FIRST PRINCIPLES OF HYGIENE

BY

W. D. STURROCK

OXFORD
AT THE CLARENDON PRESS

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PREFACE

THIS small book is based upon some experience in the correction of Hygiene examination papers. In writing it I have endeavoured to keep two main principles before my mind; firstly, that Hygiene should be considered as applied physiology—that the first essential to any comprehension of the elementary laws of health is a proper understanding of the working of the body, and secondly, that the details of Anatomy and Histology should be reduced to the absolute minimum essential to this proper understanding of Physiology. It is a common experience to find an examination candidate with, apparently, an extensive book-derived knowledge of the structure of a given organ, but with a complete ignorance of its functions: such a state of mind is obviously undesirable, and I have tried to diminish its likelihood by curtailing, as far as possible, all anatomical descriptions. In the same spirit I have, in Physiology, practically confined myself to the study of metabolism.

I have to express my best thanks to Mr. D. H. Nagel, Fellow and Tutor of Trinity College, Oxford, for his kind help in looking over my manuscript, and for many valuable suggestions.

W. D. S.

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CHAPTER I

OBJECTS OF HYGIENE

Health and disease. The object of medical science is the conquest of disease: hygiene, which is a branch of medical science, is specially concerned with the **Prevention** of disease. The doctor in his daily work endeavours to cure persons who are already the victims of illness, but the hygienist endeavours so to control the conditions of life as to make disease less likely and less frequent. It must be remembered that every man, however strong and healthy, is *liable* to disease: his life may, in one sense, be considered as a constant struggle against disease, and day by day his own healthy constitution is pitted against the forces of invading illness. As will be explained more fully later on, we have all of us a certain power of resistance to these attacking forces: without this resisting power we should fall easy victims to the invading germs of disease, and throughout the study of hygiene it will be seen that its object is to increase the strength of this resistance, and to diminish those forces which it has to resist: hygiene is, in short, the direct and active ally of health, and the direct and active enemy of disease. By good food, good houses, good ventilation and the like, the healthy resistance, both of the individual and the community, is built up; at the same time, by all these, and by more direct methods such as disinfection, isolation of infectious illness, and purification of water, disease is deliberately attacked and the strain on our resisting forces is made less frequent and less severe. It is of the utmost importance to remember that disease may spread from one person to another, and, further, that if disease

be once established in a community, its power for evil is rapidly and enormously increased: one victory to disease makes it more powerful in its further attacks on other persons. It is plain that this fact is of greater significance in populous countries than in the simple life of the prairie or the forest, and history and experience show only too clearly, in the Black Death and other plagues, that unchecked disease may ravage whole countries in the most terrible manner. Now it is equally clear that with our crowded cities and our complex civilization the ravages of unchecked disease would be even more complete and terrible than they were in earlier times, but, happily, side by side with our increasing civilization there has grown up an increasing knowledge of the causes and nature of disease, and an increasing ability to check its commencement, and to limit its spread.

On the foundations of this increasing knowledge and experience has been built up, very gradually, the science of hygiene. This is not yet an exact and dogmatic science, and there are many changes in its teachings, but its foundations grow more and more secure, and it is now only the details, and not the fundamentals, that alter. It is the business of the scientists to see to it that the science is progressive, but, however full and accurate their knowledge may become, hygiene, as a practical science, can never attain its full value without some understanding of its methods and its reasons by the people at large. Herein lies the importance of the dissemination of the more simple facts on which the science is based; hygiene is far more effective if people have some knowledge of the why and wherefore of the rules laid down, and are not merely given orders which they do not understand and may, very often, dislike. This is true even in an advanced civilization such as our own, but the most striking examples come from less fully civilized countries such, for instance, as India: the great difficulties with which the Indian Government have

had to contend in their efforts, by hygienic measures, to stamp out the plague, mark our point exactly. With increasing knowledge comes co-operation instead of resistance, and thus a great increase in the practical value of hygiene.

We have, so far, spoken in very general terms of *disease, on the one hand,* and of our natural *resistance to disease on the other* : it is necessary before going on to the study of hygiene proper to have a rather more clear understanding of what these terms signify. It is already clear that we have specially to consider those diseases which tend to *spread.* The term 'infectious disease' is a term in common use, and it is common knowledge that this is one type of 'spreading' disease, but spreading is a term of wider import than 'infectious': we have, then, to understand the meaning of infection, and also how it is that disease, other than infectious disease, can be of a spreading type.

Bacteria and Infection. To begin with, we must understand something of *bacteria,* for we shall find that they are intimately connected with the subject of infection.

In *bacteria,* or, as they are often more loosely called, *germs,* we find the lowest and most simple forms of life. They are so minute that it is a matter of great difficulty to appreciate their smallness. To say that the average thickness of bacteria is about $\frac{1}{25,000}$ inch may give some idea of their size, but it does not really help us much more than to say that the earth is ninety-three million miles away from the sun: both are proved facts, but they deal in dimensions that we can hardly realize. Let us merely realize that bacteria are of an extreme smallness *but* that they are alive.

There are very many different kinds of bacteria, and we see the marks of their activity all around us. When meat which is left too long becomes bad (even if flies are kept away), when a heap of leaves gradually rots, when milk turns sour—in all these things we have evidence

of the activity of bacteria of different kinds. For bacteria, being alive, need food on which to live, and this food they find in the meat or leaves or milk : further than this, they do not merely grow when nourishment is provided and conditions are in their favour, but they *multiply*—and they multiply enormously. One single bacterium, in good conditions, will soon form two, and these four, and so on and so on with extraordinary rapidity. Still further, when bacteria live on any substance (e.g. meat) they gradually change its composition, and, as a result, various chemical substances are produced : it is very often by the odour of these, that bacterial action is first made evident, but the softening of meat or the rotting of leaves, to take our former examples, afford further clear proof of the alteration of composition.

Now the direct importance of this to us lies in the fact that some kinds of bacteria find their suitable conditions in our bodies, and that they are there able to live and multiply, and set free the products special to them. Many of these bacteria, together with the products due to them, are quite harmless, but others are directly harmful, and when these get a lodgement in our bodies we suffer from disease—disease of bacterial origin.

There are many diseases to which we are subject which have been proved, by most rigorous proof, to be due to definite special bacteria, and there are many others which show by their course and their symptoms that they are also due to bacteria, though the special bacterium may not yet have been discovered. Further, some of these diseases are directly communicable from one person to another : they are, as we say, 'catching' : this means, of course, that by the breath, or from the clothes, or by many other channels, bacteria are directly transferred from the sick person to those who are in close relation with him, and that these bacteria, in some cases, find a fresh ground on which to thrive, and so a fresh patient is struck down with the illness. Such a disease is known as an 'infectious' disease, and a person who has been in

close relation with any one suffering from such a disease is said to have been exposed to infection.

It may be said here that, in the present state of knowledge, we cannot conceive of any disease being infectious, except those diseases which are due to bacteria: it must be remembered, however, that there are many bacterial diseases which appear to be very mildly infectious, and are not usually placed in the category of infectious disease.

Let us put the important facts about bacteria in tabular form:

(1) Bacteria are living creatures which, in good conditions, will multiply and, as a result of their activity, produce various chemical substances.

(2) *Some bacteria* find their good conditions in the human body.

(3) *Some of these* produce harmful substances in the human body, and so bring about disease.

(4) *Some, again, of these* can pass directly from one person to another, and so produce *infectious disease.*

Resisting power and immunity. To any thinking person these facts about bacteria lead at once to a question. How is it that if bacteria once get a lodgement in the human body, they do not continue to live and multiply there indefinitely? In other words: how is it that we ever recover from bacterial disease?

This question leads us to the second part of our present subject—that of our powers of resistance to the invading forces of disease. Now, this subject is one of the most difficult and complex in all medicine, and we can only touch on the simplest proved facts. It is sufficient to say that we have within us a very definite power of resistance to invading bacteria, which is unconsciously exerted whenever we are attacked. The bacteria succeed in getting an entrance into our bodies, and so set up disease: gradually our resisting forces are called into action, a very real warfare begins, and one of two things takes place: either the bacteria are killed off, their

harmful products are neutralized, and we recover, or they get the upper hand of us and sooner or later we die. It is this resisting power of ours which hygiene throughout endeavours to increase, at the same time as it endeavours to decrease the powers of disease. We need not, at present, discuss the nature of this resistance ; this simple statement of the fact that we possess it is sufficient for our present need, though we shall return to the subject later when we consider the nature and the work of the blood.

This resisting power is known as **Immunity**, and, as may be readily understood, our degree of immunity differs with different bacteria. Some bacteria—for instance, that which causes distemper in dogs—are unable to do us any harm, and we are said to be *completely immune* to them. Against those bacteria which actually cause disease we only have a *partial immunity* this means that when such bacteria effect an entrance, and disease gets hold of us, we may have the upper hand of it and drive it out, or we may be beaten and succumb to it. Against some bacteria we have a greater degree of partial immunity than against others : for example, we are much better able to deal with influenza than with cholera.

We have still to define one more term in this subject of immunity, because it has a very practical bearing on hygiene. The immunity of which we have spoken at present is known as *natural immunity*, for it is part of our nature to possess it there is such a thing, however, as *acquired immunity*, and this is of two main kinds which can best be explained by examples.

(1) If a person has once had measles, he will probably never catch it again, though he may be many times exposed to infection he has, in fact, an increased immunity to measles, *acquired* as the result of his former attack. This does not apply with equal force to all diseases, but, as a rule, one attack of a disease increases our immunity to further attacks.

(2) By undergoing *vaccination* we obtain an *acquired immunity* to small-pox. Somewhat similar treatments

help to protect us against some other diseases. The why and wherefore we cannot here consider, but the importance of this fact to hygiene is obvious, for here is an instance of a direct effort towards the prevention of disease.

Let us now note three great rules on the subject of liability to bacterial disease, because, by so doing, we get a clearer and more scientific understanding of our former definition of hygiene as the ally of health and the enemy of disease. Remember that these are not mere likely suppositions, but proved rules.

A man's chances against an attack of bacterial disease depend

(1) *on the amount of the dose.* 1,000,000 bacteria are more powerful than 10,000.

(2) *on the virulence of the bacteria.*

(3) *on the resisting power of the patient.*

With the second rule we have not very much concern: the virulence, or power for evil, of some bacteria is greater than that of others, and also differs, at different times, in the same bacteria: over this difference in virulence hygiene has not much control. The first and third rules, however, point the way for the efforts of hygiene, and show the twofold scope of its work: the destruction of bacteria, and the building up of health and resistance. It should be mentioned here that a successful result in this latter direction increases our resistance to many diseases which are *not* of bacterial origin.

It should now be clear how disease may be of a spreading type, without being 'infectious' in the sense recently defined. A few examples will show this most simply. Suppose the water supply of a town to contain disease germs: the specific disease which they produce may run throughout the town, without any one person catching it directly from another. Similarly, if cattle be tainted with disease, that disease may be spread either by the meat sold from the butcher's shops or the milk from the dairies.

Or again, to take a very different case, if work in

a chemical factory, in which poisonous fumes are produced, be carried on without proper precautions, the ranks of the workers may be weakened and decimated by disease. In each of these examples we get many cases of disease due to one particular (and preventible) cause.

Secondary objects of hygiene. Though the primary object of hygiene is the prevention of disease, it endeavours also to teach people how to add to the comforts of their life: more particularly how they may combine comfort with economy, and manage their houses in a more scientific manner, 'more scientific' in this case practically meaning 'less wasteful'. It should never be forgotten that all the advantages which a knowledge of hygiene brings with it arise from the experience gained in our continuous fight against disease, and that all the comforts of good grates and fires, good food and cooking, good clothes, good ventilation and the like, are simply accessories to hygiene.

A little warning may, perhaps, be useful here: the increase of interest in the science of health has brought with it, not only benefits, but also evils, in the shape of armies of faddists, all of whom think their own particular fad is the cure for all ills. Almost every article of food has been described as poison by one writer, and as the one thing needful by some other: some put their faith in cold-water cures, and others in hot-water cures: some think nothing else will matter if only they live on a gravel soil, and others if only they wear Jaeger underclothing. Many people, too, wherever they go, discuss their ailments with each other, and seem to think of nothing but their health. Hygiene teaches none of these things.

Though much has been said, in the preceding pages, about our constant struggle with disease, it is important to remember that nature has endowed us with a wonderfully competent resisting power. Hygiene, therefore, does not teach us to live in constant fear and anxiety, but shows us how we may, in a sane and rational manner, give ourselves the best of chances.

The man whose thoughts are centred on his health, and his food, and his underclothing has a poor life of it, and is a nuisance to his neighbours : the true hygienist learns how to steer a rational middle course between dangers on the one hand and fads on the other, and then leaves his health to fight its own battles.

CHAPTER II

THE HUMAN BODY

THE needs of the human body cannot be understood without some knowledge of its structure and its functions. **Anatomy** is the science which tells of the *structure* of the body, and the arrangement of the organs of which it is composed : **Physiology** is the science which tells of the *functions* of these organs—what they have to do, and how they do it. It will be well to give, in the first place, a simple statement of the main physiological processes which we have to consider, and, later, to describe these processes, and the organs concerned in them, in rather more detail.

There is one great physiological fact which is our starting-point—*the living body is constantly wearing away.* All through life there is a constant process of *disintegration*, or breaking down, taking place in the tissues of which the body is composed.

With this fact granted, two more become obvious :

(1) *Something is regularly needed to replace the waste.*

(2) *The waste products must be got rid of.*

These are the three main facts about physiology, so far, at any rate, as it concerns us in the study of hygiene. To keep us in health, there must be a regular **intake** into our bodies, and a regular **output** from them. If intake = output, we maintain our weight : if intake is greater than output, as is the case in growing children, weight increases : if intake is less than output, as in starvation, weight is lost.

Now it is clear that if our tissues break down, and the waste products are passed out of the body, the fresh substances that we take in must be actually built up into these tissues—in other words there is always a process

of *assimilation* accompanying that of disintegration. The accompanying diagram takes us as far as we have reached, and we can now begin to elaborate it.

Our *intake* consists of *food and water*, and of *oxygen*, one of the gases of the air. The water and oxygen are absorbed into the body unchanged, but the food must first be transformed, before it is fit to be absorbed—it has to undergo the process of **digestion.** After digestion, the transformed food is absorbed, like the water and oxygen, into the system. All the absorbed matters have now to be distributed over the body; this is done by the **circulation of the blood,** and in the various parts of the body the absorbed matters are assimilated into the tissues. Here also the corresponding disintegration takes place and the circulation now carries away the waste products to the organs which perform the duty of getting rid of them: this process of getting rid of waste matters is known as **excretion.** There is one more process to be mentioned—that of **respiration** (or breathing), a process which is concerned both with intake and output. By respiration we take in the oxygen, of which we have spoken, and pass out another gas known as carbonic acid gas. It will be seen that the circulation of the blood is the chain which links up all these processes of digestion, respiration, and excretion. The water and oxygen, and the digested foodstuffs are all absorbed into the blood, and distributed by the blood to the various parts of the body and the waste products, in their turn, are carried off by the blood to the excretory organs and then passed out of the body altogether.

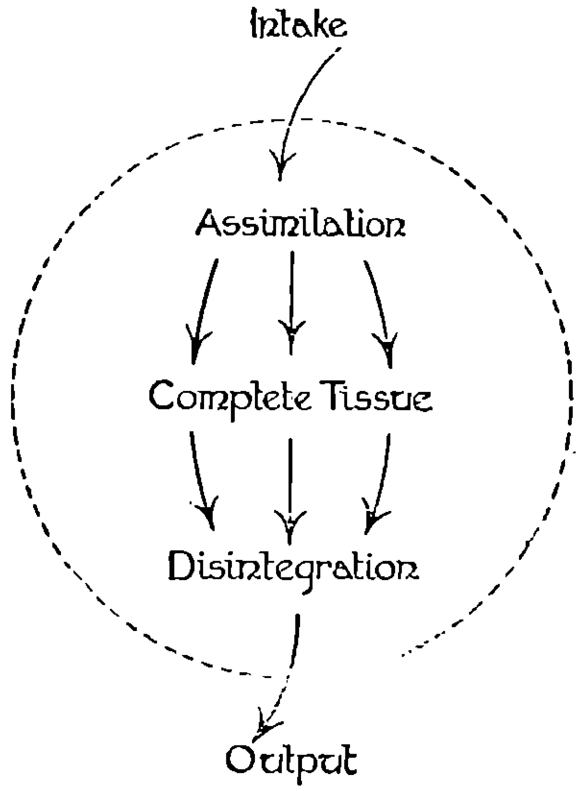

FIG. 1. Diagram of assimilation.

All these subjects of intake and output—of digestion, absorption, respiration, and excretion—may be grouped together under one heading, in the term **metabolism**, which it will be convenient for us to use. The broad subject of metabolism, though it is only one of the subjects included in physiology, is practically the only branch of physiology which concerns us as students of hygiene.

The diagram (Fig. 2), which is simply an elaboration of Fig. 1, represents the broad facts of metabolism which

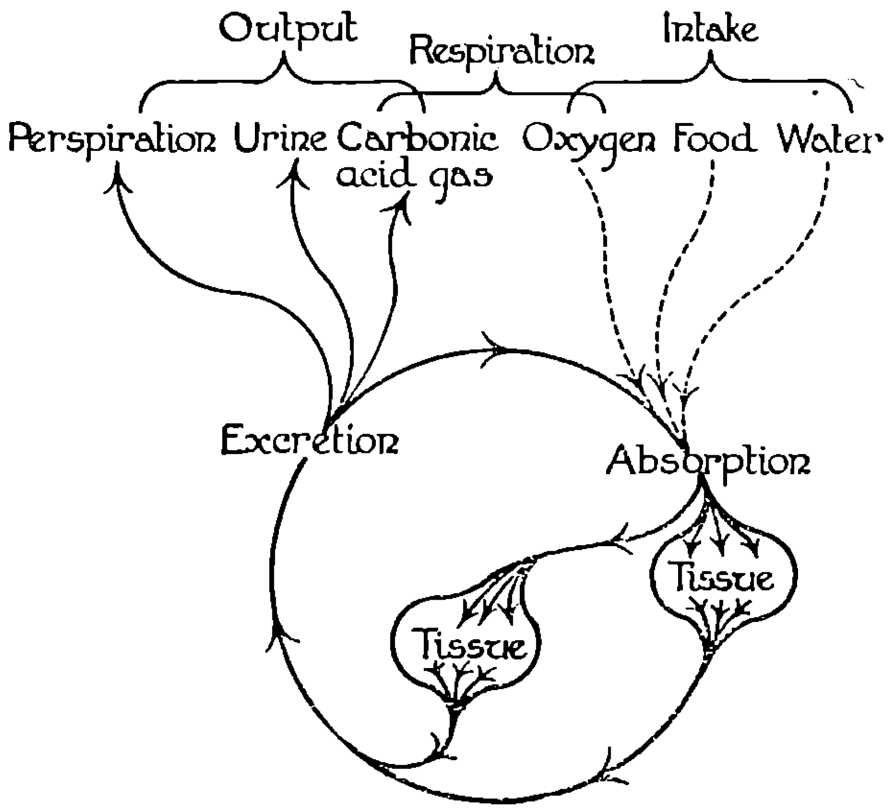

Fig. 2. Diagram of assimilation.

we have so far merely stated, and which we shall by degrees study in greater detail. The circular line represents the *circulation*, which links up the various processes of the bodily mechanism.

Anatomy. We cannot proceed further with physiology without knowing something of the structure of the body and the arrangement of the organs whose functions we have to learn.

The whole body—head, trunk, and limbs—is built up on a framework of bone, known as the *skeleton*. With the actual arrangement of the bones we have but little

concern, but their purposes and uses are of great importance. The skeleton gives shape and firmness to the body: if our bones were to soften we should be inert and shape-

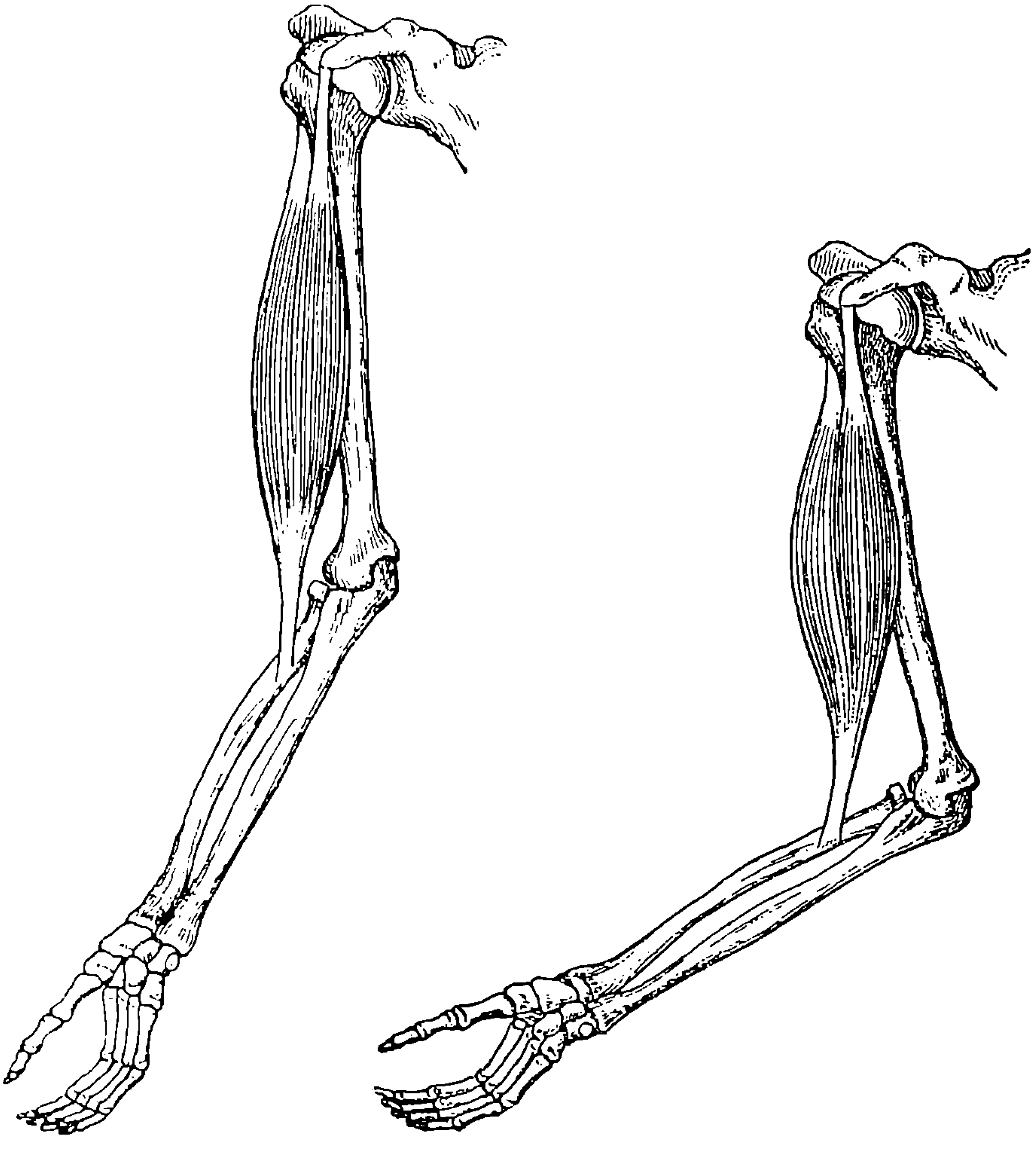

Fig. 3. Muscles of arm.

less, incapable of standing erect or of moving. If our bones do not grow equally on each side, or become diseased, deformities such as spinal curvature or hunchback result. Bones are hard, and, when they are exposed to force, are almost unyielding: violence does not bend a healthy

bone out of shape, but breaks it across : a 'broken leg' means a broken bone, and, as is well known, a broken leg is quite helpless.

One of the main functions, then, of the skeleton is to form a support and foundation for the rest of the body. Besides this, the bones often form a protective covering for softer parts below : the most notable case is in the head, where the bones which form the *skull* cover and protect the brain : similarly, in the chest, the spine and ribs protect the organs beneath them.

The third function of the skeleton needs some further description : the bones are clothed with *flesh*, and the flesh consists chiefly of the *muscles*. The muscles make up the chief bulk of the body, and their most notable property is that they have the power of shortening, or, as it is called, of *contraction* : they are also *elastic*, which means that after contraction, *they relax to their former length*. Now, the muscles which form the flesh are attached at their two ends to bone, one end to one bone and the other to a second bone, the attachment being usually by means of *tendons*: these tendons simply serve the purpose of strings or ropes, and are not contractile.

What, then, is the effect of the contraction of a muscle? Obviously, since the bones do not bend out of shape, it must be the *movement* of one bone towards another ; the various bones are jointed to each other so that such movements can take place freely, and in a precise and regular manner. The skeleton, then, has three functions :

(1) It provides a foundation and support for the body.

(2) It gives protection to some of the soft parts.

(3) It provides points of attachment for the muscles, and on the property of contraction of the muscles and their proper attachment to bones *depends all our power of movement.*

Remember that if bones are moved, all the soft parts to which they give shape and support must move with them. If we move the bones of our legs, we move the legs themselves.

The muscles, in their turn, are clothed with a layer of fat which varies in thickness in different parts of the body. All through bones, muscles, and fat ramify innumerable *blood-vessels* and *nerves* which link all the parts of the body together, and over all lies the skin, which also has a blood and nerve supply.

The muscles which form the flesh are known as *voluntary* muscles, for they are under the control of the will; we move our arms and legs, stand up or lie down, run or stay still when we want to, and the muscles which produce these various actions are governed by our brains. The various internal organs are, however, also endowed with muscles, but these act without our having any control over them and are known as *involuntary* muscles. The heart, as will be described later, is a muscular organ and is constantly contracting and relaxing, but we cannot stop it doing so nor are we even conscious (in health) of its action. Similarly, the various organs of the abdomen contain muscles, which do a great deal of active work without our wills doing anything to control them. The mistake is often made of saying that the muscles which control our breathing are also involuntary, but a little thought soon shows this to be wrong; any one can hold his breath, or take a long breath, or cough at his pleasure; true, we cannot hold our breath indefinitely, but this is merely due to the fact that we cannot live without breathing and that the urgent desire for breath overcomes our will-power.

Together with this difference between voluntary and involuntary muscles, there is also a difference in structure, and heart muscle has a structure more or less intermediate between a voluntary and a typical involuntary muscle. *All* muscles are, however, *contractile and elastic.*

Here it will be well to define what we mean by the terms **tissue** and **organ**, both of which have been used already, but left undefined. The whole body is built up of innumerable *units,* which are known as **cells**, of diverse shapes and sizes, but yet having a similar structure.

We spoke, in the last chapter, of bacteria as showing one of the simplest forms of life: a bacterium may be considered as a body composed of *one cell.* We learned, further, that bacteria divide and multiply: if, instead of separating, the two divisions remained combined we should get an organism composed of two cells, and the next division would produce four cells, and so on: eventually we might obtain an organism composed of a vast number of cells.

Now suppose that, after reaching the four-cell stage, the two cells on the right grow in a different manner, and take on a different appearance, to those on the left: we then get what is known as *differentiation of structure.* This gives a rough idea of what takes place in the human body, which grows from a single cell: the process is one of such complexity that we cannot attempt to follow it, but, by degrees, different groups of cells take on different characteristics, *and grow into different tissues.* The tissues, then, are the different kinds of material—skin, muscle, fat, bone, &c.—each with its own definite cellular structure, of which the body is built up. An *organ* is a 'natural part' of the body, with a special construction and purpose, or function. The heart, the liver, the stomach are all organs: each is a definite part of the body, with a special function to perform, and a construction peculiar to itself.

Those organs with which we are chiefly concerned lie in the trunk, and the trunk contains two cavities separated from each other by a partition of muscle which is known as the *diaphragm.* Remember that the diaphragm is a muscle, and so has the power of contracting, for on this power much of its importance depends.

The upper cavity of the trunk is the *thorax* or chest, and the lower is the *abdomen.* The thorax is enclosed within the ribs, but not entirely, for the ribs do not meet each other either in front or behind: in front they join a dagger-shaped bone, which can be easily felt, and is known as the *breast-bone*: behind they join the spinal

column or *spine*. The spine is composed of thirty-three bones known as *vertebrae*, which succeed each other the whole way down the back, from the head to the lower part of the trunk, and form a column of great strength: if the spine was composed of one single bone, the back would be always stiff and we could bend neither backwards and forwards, nor sideways, but its formation of many bones joined together allows considerable movement, without sacrificing strength. It is important to remember that there is very little movement of each bone upon the next, and that the considerable play which the spine allows is the *sum of a large number of small movements*. Since the ribs enclose the thorax, and the diaphragm separates the thorax from the abdomen, it is plain that the diaphragm runs from the lower ribs on one side to the lower ribs on the other.

The **thorax** contains the *heart* (with the great vessels that leave and enter it) and the *lungs*. The lungs are much the larger organs and fill up each side of the thorax; the heart lies between the lungs, but rather more on the left side than the right; the lungs are, so to speak, moulded upon the heart, and the left lung, in particular, overlaps it and covers up much of its front surface. A small part of the front surface is, however, left uncovered by lung, and near this part the heart may be felt beating in most persons the back of the heart is but little encroached upon by the lungs, and is in close relation with the spine.

Besides the heart and lungs, there is a tube, the *gullet*, running right through the thorax, close to the back: this passes from the mouth and nose above, to the stomach in the abdomen below. There is also in the upper part another tube, the *windpipe*, which passes from the mouth and nose to the lungs: this divides into right and left parts soon after entering the thorax. Obviously both these tubes must pass down the neck, the windpipe lying in front of the gullet. It is important to remember that when we speak of a 'cavity' such as the thorax or

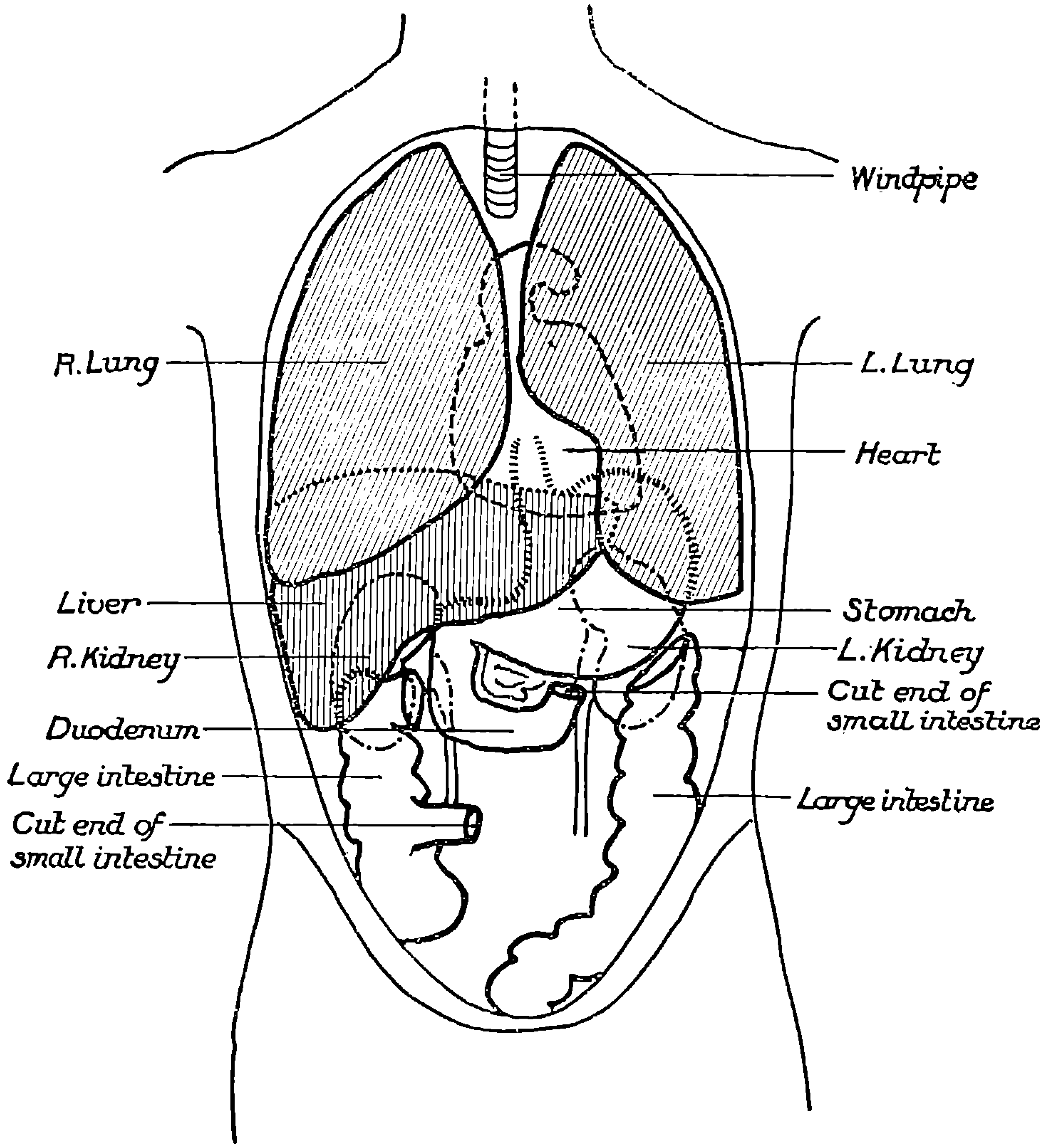

Fig. 4. Organs of the body (modified from *Landmarks of Surface Anatomy*, by L. B. Rawling. Lewis).

The figure on the opposite page should be carefully studied while the descriptions of the various organs are being read. It is quite diagrammatic and is only intended to represent the relations of the *outlines* of the various organs, the organs themselves being considered transparent.

The transverse portion (p. 29) of the large intestine is, for the sake of clearness, supposed to have been removed; so also is the whole of the small intestine, with the exception of the first part—that part which is fixed to the abdominal wall. This part of the intestine is known as the duodenum; between the duodenum and the stomach a part of the pancreas can be seen.

Note that—

The right lung overlies the heart and the liver;

The left lung overlies the heart, the stomach, and the upper edge of the left kidney

The heart overlaps the edges of the stomach and the liver;

The liver overlies the stomach and the right kidney;

the stomach overlies the left kidney,

and the large intestine overlies both kidneys.

The two ureters are to be seen extending from the kidneys towards the bladder, which is not figured.

abdomen, we must not conceive of a sort of box into which things are loosely fitted. Every fragment of space is filled up *completely*, and all the various organs are moulded on each other and on the sides of the enclosing walls of the cavity.

The **abdomen** contains the organs of digestion and the main organs of excretion. Now the diaphragm is not a flat sheet running straight across the trunk, but has a domed shape and arches up under the ribs. Consequently, the upper organs of the abdomen get some protection from the lower ribs. The lower part of the abdomen is also enclosed in bone: here the two large hip-bones, one on each side, meet each other in front and join the lower part of the spine behind. In this part the vertebrae are so completely joined to each other that they form one bone, the *sacrum*, and no longer have any movement at all on each other movement is unnecessary here, and everything must give way to strength, for the hip-bones and sacrum have to bear all the weight of the body above. The walls of the abdomen between the hip-bones and the ribs are composed of strong sheets of muscle.

The *liver*, which is a solid organ, is the largest and heaviest in the body, and is placed in the upper part of the abdomen closely applied to the under surface of the diaphragm: the bulk of the liver is on the right side, and it gradually thins off upwards and to the left: the right side of the liver is just covered by the ribs.

The *stomach* is a hollow organ, and lies high up in the abdomen, where it is in contact with the left part of the diaphragm. The organ is more or less pear-shaped, the wide portion on the left, and the narrow under the liver and pointing to the right. The gullet opens into the stomach close under the diaphragm, and the narrow right end of the stomach passes into the small intestine. The stomach differs from the liver in that it is hollow and constantly changing its shape.

The *small intestine* is a very long tube, coiled in intricate

convolutions, which fills up most of the central part of the abdomen. It is about twenty-three feet long, and is able to move freely (except in the part near to the stomach where it is closely held to the back wall of the abdomen), so that the relations of the various convolutions to each other are constantly changing. The small intestine ends rather low down on the right side and passes into the large intestine.

The *large intestine* is rather more closely bound to the back wall of the abdomen than the small it cannot, therefore, move so freely, and its different portions have more definite positions in the abdomen: it passes first up the right side, then right across the front, and then down the left side, when it gradually trends towards the middle line and passes deep down between the hip-bones, and so to the outside of the body.

It is clear now that there is one continuous tube, which varies in its character at different parts, passing from the mouth above to the large intestine below, and so running right through the body. The stomach is only a specially shaped and wider part of this tube, and the whole tube—gullet, stomach, small and large intestines—is known as the **Alimentary Canal.**

In close relation with the first part of the small intestine is a rather loosely formed narrow organ, running across the *back* of the abdomen, the *pancreas*. This is an organ of great importance to digestion, and from it a very fine tube, the *pancreatic duct*, runs to open into the first part of the small intestine. Close beside its opening there is the opening of another fine duct, the *bile duct*, which runs to the small intestine from the liver. Here we have a reason for the binding down of this first part of the small intestine: if it were free to move these fine ducts would run the risk of being stretched and torn.

There remain in the abdomen the organs concerned with excretion. These are the *kidneys* and the *bladder*. The kidneys are two solid organs (about 3½ inches long and 2½ wide) which lie, one on each side, close against the

back: they are high enough up to be partly covered by the lower ribs at the back: their shape explains itself, for they have given rise to the expression 'kidney-shaped'. The *bladder* is a hollow organ lying very low down in the front of the abdomen: it is placed right in the middle, and is ordinarily covered by the two ends of the hip-bones as they meet in front. The kidneys are connected with the bladder by two fine tubes—the right and left *ureters*, and the bladder with the outside of the body by another fine tube—the *urethra*.

The stomach and the bladder have been described as 'hollow' organs: they have, however, soft walls, and, from what has been said of the true conception of a 'cavity' such as the abdomen, it should be clear that, when they are empty, they are merely flat *bags* with their walls in contact.

We need little more general anatomy to understand hygiene, except a short description of what is known as the **nervous system.** The bones which compose the skull form a cavity which is completely filled up by the *brain*, the great centre of the nervous system. At the bottom of the skull is one large hole, and through this passes a prolongation from the brain which is known as the *spinal cord*. Every vertebra in the spine is pierced through from above downwards, so that when the bones are in position there is a continuous tunnel—the *vertebral canal*—in which the spinal cord is safely lodged, for the spinal cord, like the brain, must be carefully protected from external violence. Between *each* pair of vertebrae a pair of *nerves*—right and left—runs out through holes between the bones, and these nerves break into branches which are distributed all over the body. The spinal cord ends in the small of the back, but the vertebral canal reaches right down the trunk, and the lower part is occupied by a bundle of nerves, which have been given off from the spinal cord, and by degrees pass out to the body between the lower vertebrae.

Two more facts may be mentioned before we pass on

to a description of the circulation: one is that the cavities of the mouth and nose have no connexion whatever with the cavity of the skull: people who do not realize this are apt, when shown the hole (for the spinal cord) in the bottom of the skull, to say that the gullet passes through it. The second is, that the large nerves and blood-vessels are big things, and not, as many people think, minute strands: the largest blood-vessel in the body is fully as thick as the thumb, and the largest nerve is nearly as big as the little finger.

We are now able to consider in detail the **circulation of the blood**, and the manner in which it serves to join up all the physiological processes which take place in different parts of the body: the blood itself—its composition and its functions—will be described later.

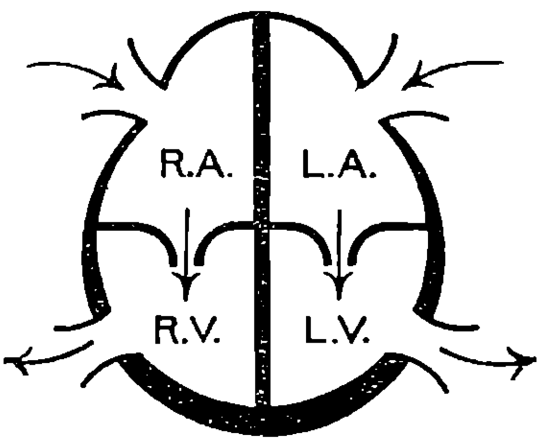

FIG. 5. Diagram of heart.

The *heart* is the great centre of the circulation, and, as we know, is placed in the thorax: it is, roughly, about the size and shape of the clenched fist with the knuckles of the thumb and forefinger pointing downwards and to the left. The heart is a hollow organ (so that it can contain blood) and is divided into four chambers, two on each side; *those on the right side have no direct communication with those on the left.* The chambers are known as *auricles* and *ventricles*: the auricle, on each side, is placed *above* the ventricle, and opens directly into it: blood *enters the auricles,* passes from them into the *corresponding* ventricles, and so passes out of the heart again. The diagram expresses our present knowledge of the heart: R.A. and L.A. signify right and left auricles, and R.V. and L.V. right and left ventricles.

Now *the walls of the heart are composed of muscle,* and consequently have the power of contracting. We spoke of the flesh muscles as being attached by their two ends

to bone: here we have a different arrangement of muscles, which have no definite end or beginning, but form the walls of a hollow chamber. What is the effect of the contraction of these muscular walls? The effect *must* be that any blood contained in the chamber is driven out, and the walls come together. If a rubber ball, with a small hole in it, is filled with water and then squeezed, the water is expelled in a jet, as most readers have proved by practical experiment. Imagine the rubber ball to have the power of contracting, instead of needing external force, and we get the condition of the heart.

Look, now, at L.V. in the diagram and suppose it to contract: it appears from the diagram that blood will pass both into L.A. and out of the heart altogether: this, however, is not the case, for in the aperture between L.A. and L.V. there is placed a *valve,* which allows blood to flow from L.A. to L.V., but at once closes when blood tries to flow from L.V. to L.A. Our diagram is correct in so far as it shows that when L.V. contracts blood must, naturally, *try* to pass from L.V. to L.A., but it fails to show that, when this happens, the *aperture becomes closed,* and consequently the only aperture left is that which opens out of the heart. *When the left ventricle contracts, then all the blood in it is forced out of the heart.* There is also a valve between R.A. and R.V., and all that we have said of L.V. applies to R.V. also.

We have hitherto been content to say that the blood *does* flow from the auricles to the ventricles and so out of the heart we may now say that it *can only* flow in this direction.

Remember that we have said of muscle that it is elastic, and that, therefore, after contractions, it is able to relax and return to its original shape: the ventricles of the heart, after contraction, relax again and are filled with blood from the auricles. Now the ventricles contract about seventy times a minute in an adult, and therefore drive a certain quantity of blood out of the heart about seventy times a minute: on this repeated contraction

(or we may call it pumping) of the ventricles depends the circulation of the blood : *the contracting ventricles supply the driving power of the whole circulation.*

Let us now follow the blood which is driven out of the *left ventricle* : it all leaves by one vessel, known as the *aorta.* At the commencement of the aorta there is another valve which completely prevents the blood, once it is in the aorta, from passing back into the left ventricle: like the valve between the auricle and ventricle it only allows one course to the blood. The aorta very soon gives off branches which run to the head, neck, and arms, and then passes down the back of the thorax and abdomen (passing through the diaphragm) : it gives off branches, all the way down, both to the walls of these cavities and to the organs contained in them, and some of its lower branches pass off to supply the legs. The aorta, and all its branches, are known as *arteries,* and the definition of an artery is ' a vessel which carries blood *from* the heart *to* the tissues '. All these arteries which come off from the aorta divide and subdivide into smaller and smaller branches, until they form *arterioles* (which are merely small arteries).

The arterioles are found in every part of the body and every arteriole is ultimately derived from one single vessel, the aorta. The arterioles themselves subdivide and form a different type of vessel. The large arteries have thick stout walls, which, as we pass down to the arterioles, become gradually finer and thinner, as the vessels become smaller : the subdivisions of the arterioles are vessels of an exceeding smallness, with walls which are only *one cell thick,* and are known as *capillaries.* Capillary means ' hair-like ', but these vessels are really much finer than hairs, their diameter being about $\frac{1}{3000}$ inch, while that of a human hair is about $\frac{1}{500}$ inch. Here again, as with bacteria, we are dealing with very small measurements : the figures, however, give some idea of how minute a capillary is.

The capillaries permeate all the tissues of the body, so

that the blood within the vessels is separated from the tissues outside by one single layer of cells: remember, however, that the capillaries are true vessels and form a fine network and not an open spongework. Now it should be clear, from what has been said before, that the blood is engaged in carrying substances, which it has absorbed, *to* the tissues, and, in turn, carrying various waste products *from* the tissues: there is, in fact, an interchange between tissues and blood. *This interchange takes place in the capillaries,* so that, in a sense, *the capillaries are the essential part of the circulation.* The heart

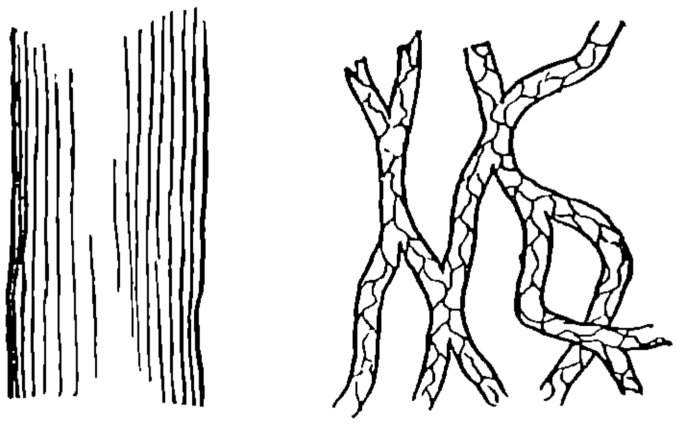

FIG. 6. Diagram to show relative diameters of a human hair and human capillaries. Magnification × 250.

and the great vessels with their smaller branches are merely a mechanism by means of which an efficient capillary circulation is maintained.

The capillaries gradually come together and form *venules* (or small veins), and these in turn form the *veins,* which perform the function of carrying the blood back to the heart. The veins are rather like the arteries as they are simply vessels along which the blood is carried, but they do not have such stout walls.

The veins from all parts below the heart collect into one large vessel, the *inferior vena cava,* and those from above the heart into the *superior vena cava*: these two vessels open direct into the heart.

In the veins, as may be expected, the blood does not

run so strongly as in the arteries, and there is also a constant tendency, when we are standing up, for the blood in the lower part of the body to run downhill, away from the heart: the circulation in the veins is therefore helped by numbers of *valves*, placed at intervals of some inches, which only allow blood to flow past them towards the heart; it is also helped by the fact that the various muscles, when they contract, squeeze the blood along the veins which lie among them: also, as will be more clear later, blood is squeezed towards the heart every time we breathe. Remember, however, what we have already laid stress upon—that the real driving power comes from the left ventricle of the heart, even though it acts less directly on the veins than on the arteries.

The inferior and superior vena cava pass directly into the right auricle, so that the blood from the *left ventricle*, after being distributed all over the body, is brought back to the *right auricle*. From the right auricle, as the diagram shows plainly, the blood must pass into the *right ventricle*, and from the right ventricle it is again driven out of the heart, and we must again follow its course. Now, as the left ventricle drives the blood to the body in general, it is evident that the right ventricle must have some special function. *This function is to drive blood to the lungs.* The outgoing vessel (which corresponds to the aorta) is the *pulmonary artery*, and, at its commencement, as in the aorta, there is a valve which prevents blood getting back to the heart. The pulmonary artery soon divides into two branches, and one branch goes to each lung. The arteries divide and subdivide, and eventually form capillaries in the substance of the lungs. The capillaries unite again to form small veins, and these eventually form the *pulmonary veins*, which bring back the blood to the heart, entering the *left auricle*. From the left auricle the blood enters the left ventricle, and all that we have described takes place again.

We have, therefore, followed the blood the whole way round the circulation, and have seen that its course is

divisible into two parts which may be tabulated and named as follows

Left ventricle→whole of body→right auricle=*general circulation.*

Right ventricle→lungs→left auricle=*pulmonary circulation*, or *lesser circulation.*

As may be expected, the right ventricle, which has only to drive the blood through the lesser circulation, does not need so much power as the left, and its walls are not so thick and strong. If we bear in mind that there is no *direct* communication between the right and left sides of the heart, it is obvious that blood which leaves the right side of the heart must come back to the left side, and vice versa. Remember this fact, and also one detail of the circulation—*that the general circulation starts at the left ventricle*—and the rest of the course can be worked out from this starting-point.

Now it is plain that the pulmonary circulation, so sharply cut off from the rest, must have some special function. We have already realized that the capillaries form the essential part of the circulation ; we therefore find the key to the special function of the pulmonary circulation by examining the pulmonary capillaries. In the general circulation we found that in the capillaries the blood is brought as near as possible to the tissues : in the pulmonary capillaries, the blood is brought as near as possible *to the air in the lungs.* In the general capillaries interchange takes place between the blood and the tissues : in the pulmonary capillaries, between the blood and the air. We have already learned that some of our intake—oxygen—is derived *from* the air, and that some of our output—carbonic acid gas—is given back *to* the air. This interchange takes place in the pulmonary capillaries, and is the object of the processes of respiration, which will be more fully described in the next chapter.

CHAPTER III

AIR AND OXYGEN

THE earth is surrounded by a coating or envelope of air, which is known as the atmosphere. Pure air is a mixture of gases of which two, *oxygen* and *nitrogen*, make up nearly the whole bulk, 100 volumes of pure air containing nearly 21 volumes of oxygen and nearly 79 volumes of nitrogen. Besides these two gases, air always contains a small proportion of *carbonic acid gas*; with this gas, although it is present in such small quantities, hygiene is very closely concerned. There is also present in air another gas known as *argon*; this is very similar to nitrogen, and we need remember nothing about it except its name.

All these gases are actual constituents of air, but as a rule air also contains a very variable amount of *water vapour*, and many *solid particles* (as dust) in suspension. The amount of water vapour contained in air is of great importance, even though it is not strictly a constituent of air—that is to say air would still be air even if it contained no water vapour, just as it still is air even if it contain no dust.

The following table represents the average constitution of the open air :

Oxygen . . .	20·96 parts by volume	air proper
Nitrogen (with trace of argon)	79·00	
Carbonic acid gas	·04	
	100·00 ,,	
Water vapour (very variable)	contained in air.	
Solid particles (very variable)		

It was mentioned in the last chapter that the object of the pulmonary circulation is to bring the blood into close

connexion with the air ; this is in order that the blood may be able to absorb *oxygen,* for oxygen is the essential part of the air.

Without a proper supply of oxygen all animals and plants will very quickly die : *all life is dependent on the oxygen contained in the air.*

There is another notable fact about oxygen which is that without a supply of this gas nothing can *burn.* Every one is familiar with the fact that a draught from a pair of bellows will revive a dying fire ; this is because fresh supplies of oxygen are brought to the burning coal. If a red coal, or a glowing match, is put into *pure* oxygen it will at once burst into flame ; the bellows, though they do not provide pure oxygen, provide air, which is oxygen diluted with nitrogen, and so can revive a smouldering fire.

When anything burns it is really *combining with oxygen,* and this process of burning, or combining with oxygen, is known as **combustion.** Oxygen, then, is necessary for combustion, and the reason for laying such stress on this lies in the fact that when we say it is necessary for combustion, we really say that it is necessary for *life.*

Let us now consider what this means. We said in the last chapter that the starting-point of all physiology is shown in one sentence, 'The living body is constantly wearing away'; this sentence may now be changed to 'The living body is constantly *burning* away', or, in other words, 'All the tissues of the living body are constantly combining with oxygen.'

It seems, at first sight, absurd to say that we are always burning away, but this is merely because we are accustomed to associate burning with flames and great heat. Remember, however, that burning really means combining with oxygen, and the absurdity disappears, for combination with oxygen may be very rapid or very slow ; when it is rapid we get a rapid destruction of substance, with the ordinary appearance of flames or red heat ; in the body, however, where combustion is very

slow, we get a slow and gradual destruction of tissue with a comparatively small rise of temperature. Proof of this slow combustion is given by the fact that our bodies are always hot—much hotter than the surrounding air or the inanimate objects among which we live. Now if anything is hotter than the surrounding objects it is bound to lose heat; *we are, therefore, always losing heat and yet we keep hot.* This heat is kept up by the slow burning of the tissues of our bodies; though we do not burst into flames as we walk about (as the idea of burning at first suggests), yet we do produce a definite amount of heat. The subject of the heat of our bodies, and the way in which this heat is maintained, will be discussed further in a later chapter.

We have said that combustion signifies 'combination with oxygen'. When any substance combines with oxygen, a fresh substance must be formed, and in order to understand what substances are formed when combustion occurs in our tissues it is necessary to know of what these are composed. Their composition is very complicated, and we need only mention here the three chief substances which they contain: these are *carbon, hydrogen,* and *nitrogen,* and these three substances are present in all living tissues. Carbon is a solid, and hydrogen and nitrogen are both gases, but we do not find little lumps of carbon, nor bubbles of hydrogen and nitrogen in our tissues, for these substances are all combined together to form tissue substance. It is very important to remember that when substances combine together, they may form a fresh substance totally unlike the originals; thus a combination of two gases may form a liquid, or a solid and a gas may form a gas.

The tissues, then, contain carbon, hydrogen, and nitrogen, and all these three combine with oxygen to form fresh substances; hydrogen and nitrogen may be left till a later chapter, but we must now go on to consider carbon.

When carbon combines with oxygen, the gas which

we have previously called *carbonic acid gas* is formed; now that the composition of this gas has been made clear, it will be better to use the more scientific name of *carbon dioxide*, for this name itself is a constant reminder of the fact that the gas is formed by the combination of carbon and oxygen. *Carbon dioxide is constantly being produced in our bodies, by the combustion of the carbon in our tissues.* This carbon dioxide is a waste product and an impurity, and so must be got rid of; it forms part of our 'output', and we get rid of it, as described in the last chapter, by passing it from the blood in the pulmonary capillaries into the air in the lungs.

Respiration. The process of respiration really includes all the interchange of oxygen and carbon dioxide which goes on in our bodies; it includes the processes in the *lungs* where the blood absorbs oxygen and gives away carbon dioxide to the air, and also in the *tissues* where the blood absorbs carbon dioxide and gives away oxygen. At present, however, we are concerned with what goes on in the lungs; that is to say, with *breathing.*

The lungs, as already described, are two large soft organs which fill up the two sides of the chest; they fit the chest *perfectly,* and by means of the windpipe, and the mouth and nose, they are in communication with the outside air. They are not merely open bags full of air, but they have a structure more like that of a very fine sponge than any other ordinary object; with this very important difference, that, instead of being full of tubes and channels which communicate with each other, there are an immense number of minute 'blind alley' chambers, or *air-sacs,* which all communicate by tubes with the windpipe, but do not communicate with each other; since these air-sacs are all definite little chambers, air cannot pass right through a lung as water does through a sponge. The windpipe, soon after it enters the thorax, divides into two large tubes, the right and left *bronchi,* which pass to the right and left lungs respectively. Each bronchus divides into two, and the process is repeated

again and again and again until there are eventually an innumerable number of minute tubules each opening out into an air-sac. The walls of these air-sacs are one cell thick, and there is a close network of capillaries between the walls of the adjoining sacs, so that the air in every air-sac is only separated from the blood in the capillaries by two layers of cells, and free interchange of gases can

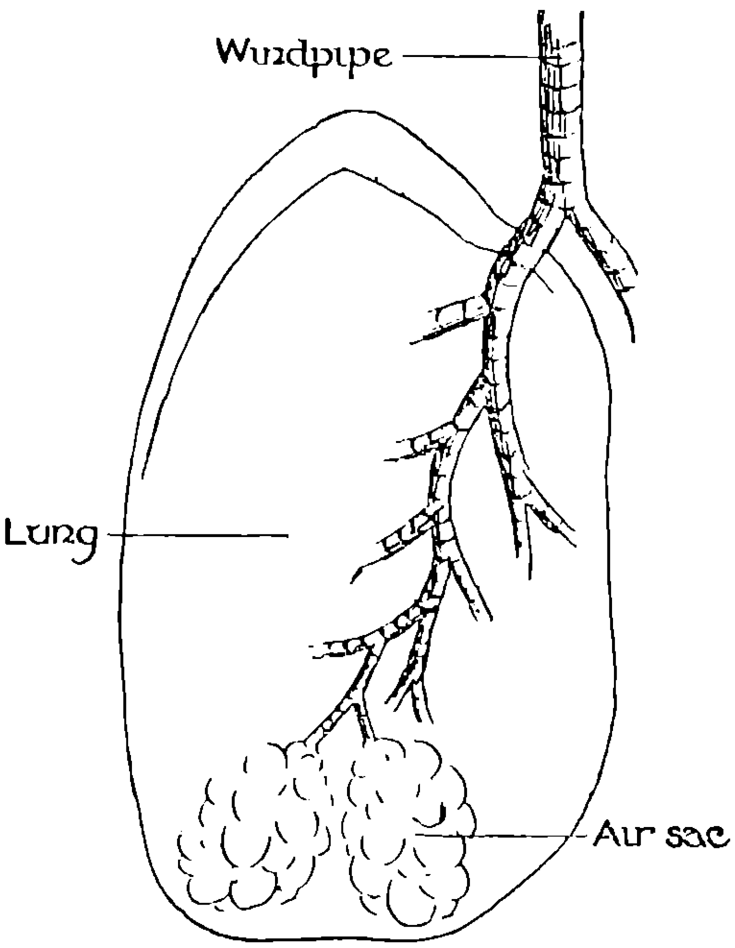

Fig. 7. Diagram of structure of lung. The air-sacs are, for clearness, drawn very much too large.

take place. If the lungs were merely wide open bags one cell thick interchange of gases could still take place, but it would only affect the fringe of the big air space; the great bulk of the air would be unaffected. The arrangement of a vast number of air-sacs allows an infinitely larger amount of air to be brought into connexion with the blood, for the walls of a vast number of small chambers are much more extensive than the walls of one single large chamber; *the structure of the lung allows of a very rapid and complete interchange of gases.*

Air is not allowed to remain stationary in the lungs, but is passed in and out about sixteen times a minute in an adult, and more often in a child, so that the carbon dioxide is passed away into the open air and fresh supplies of oxygen are brought in.

To understand the way in which this breathing is carried on we must again lay stress on the fact that the lungs fit the chest exactly, and also on the fact that, since they are in open communication with the outside air, they are always full of air, however much they may alter in size. Consequently, if we can increase the size of the chest we will increase the size of the lungs, for they always fit the chest exactly, and fresh air will be drawn into the lungs, for they are always full of air.

We pass air in and out of our lungs by alternately increasing and diminishing the size of our chests.

Enlargement of the chest is produced by the contraction of certain muscles, and, of these, the most important is the *diaphragm.* This has already been described (see p. 24) as an arched sheet of muscle running from the lower ribs of one side to the lower ribs of the other side, and separating the chest from the abdomen ; since it is a muscle it can contract, and the diagram shows what happens when it does so. It cannot pull the ribs towards each other, for other muscles contract at the same time and hold them steady, and so it *must* become flatter and less arched. The chest, therefore, becomes *deeper from above downwards,* and the lungs enlarge downwards.

At the same time the size of the chest can also be increased by the contraction of the muscles which close in the gaps between the ribs—*the intercostal muscles.* The effect of the contraction of these muscles is to make the chest *wider* and *deeper from front to back.* In quiet natural breathing the diaphragm does nearly all the work, but in deep breathing the intercostals are also brought into play. If as deep a breath as possible is taken some further space is gained by the contraction of a number of the muscles of the neck, chest, and back.

Any one can prove the increase of the size of the chest in deep breathing by the use of a tape-measure.

By muscular action, then, we are able to increase both the depth and the width of our chests ; the lungs, therefore, increase in size and fresh air is drawn into them. The air may enter by way of either the mouth or the nose, but preferably by the latter, for by this route it is *warmed* and *filtered* more effectively before reaching the lungs. Nose breathing is really a matter of great importance,

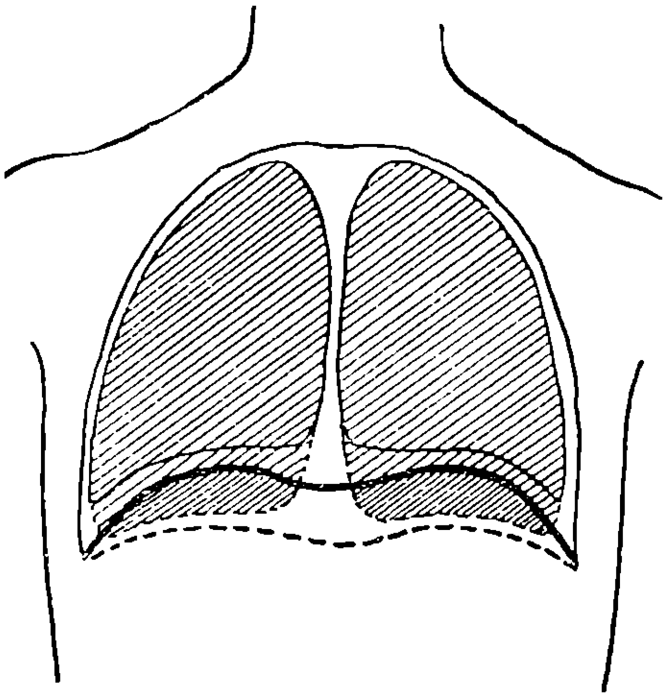

FIG. 8. Diagram to illustrate expansion of thorax due to contraction of diaphragm.

and the mouth should always be kept shut ; if a child *cannot* breathe through the nose it is a sign that something is wrong, and a doctor should be consulted so that the cause of the obstruction may be found ; the most common cause is the presence of the growths called *adenoids* at the back of the nasal passages. Both mouth and nose open into a common cavity known as the *pharynx*, from which both windpipe and gullet lead off, the windpipe lying in front. At the commencement of the windpipe is a small chamber called the *larynx* in which lie the *vocal chords* ; the vibrations of the vocal chords, caused by the passage of the air, produce the voice.

The windpipe is kept constantly open by the presence in its walls of incomplete rings of a hard substance known as *cartilage.*

When the muscles relax the chest returns to its former size, and air is again passed out ; besides this, if we wish to breathe out an extra amount of air, we are able to contract the chest still further by the use of other muscles, of which the most important are the muscles in the wall of the abdomen. When these contract, they press upon the abdominal organs, and these in turn must press upon the under surface of the diaphragm, and so tend to reduce the size of the chest : by putting the hand on the abdomen the muscles of the abdominal wall can easily be felt to contract, when we cough, or when we breathe out as deeply as we can.

The fact that, in the lungs, there is an interchange of gases between the air in the air-sacs and the blood in the capillaries, makes it quite clear that the air we breathe out (*expired* air) cannot have the same composition as the air we breathe in (*inspired* air) ; it will contain less oxygen and more carbon dioxide. The following tables show the average compositions of inspired and expired air, in parts by volume :

	Inspired air.	*Expired air.*
Oxygen .	20·96	16·50
Carbon dioxide	·04	4·50
Nitrogen	79·00	79·00
	100·00	100·00

The expired air also contains a much larger amount of *water vapour,* for we are constantly losing water from our bodies, and this is one of the ways in which the loss occurs.

All living creatures, animals, and plants, abstract oxygen from the air and yield carbon dioxide in return ; further, when wood or coal is burnt, carbon dioxide is given off to the air. Thus we should expect that, by

degrees, the amount of carbon dioxide in the atmosphere would be increased. That this is not so is due to the fact that, when they are in sunlight, the green leaves of plants perform exactly the opposite process; that is to say, they take in carbon dioxide and give off oxygen, and they do this far more vigorously than other parts of the plant absorb oxygen and give off carbon dioxide; consequently, the total effect of the activities of vegetable life upon the atmosphere is a reduction of carbon dioxide and an increase of oxygen. As we shall see later on we can get our necessary carbon only by eating food; plants obtain theirs directly from the carbon dioxide in the atmosphere.

The average composition of the atmosphere, therefore, remains unaltered, but, as may be expected, there is rather more carbon dioxide in the neighbourhood of towns than there is on the top of a mountain. This difference is not, however, very marked, for the air near a town is free to mix with the purer atmosphere all around it, but when we consider the condition of the air in a *confined* space we find much more marked differences; the air in a crowded room contains very much more carbon dioxide than the air outside. Now *carbon dioxide, in excess, is an impurity in air*, and if it is present in more than a certain small percentage, it is directly injurious to health: the heat of the room, and the water vapour and organic matter[1] in the air probably have something to do with this injury to health, but their effects are much less understood, and the percentage of carbon dioxide present is much the best test of the purity or impurity of air. The only way in which the carbon dioxide in air can be kept down to its proper level, is to provide a free supply of fresh air, and this supply is ensured by good **ventilation.** We shall find that the subjects of *ventilation* and *heating* are closely connected with each other, and must, to some extent, be studied together: for the present

[1] Organic matter is matter, whether solid, liquid, or gaseous, which is derived from animal or vegetable life.

we shall merely discuss the question of how much fresh air every person ought to have, and leave the subjects of the provision of proper ventilation and heating until we study the construction of houses and other buildings.

It is generally held that the amount of carbon dioxide in the air of a room ought not to exceed *0·06 per cent.*; average air, as we have seen, contains 0·04 per cent., so that an extra 0·02 per cent., or 2 parts in 10,000, makes the difference between pure and impure air. As a matter of fact this amount is very often exceeded in ordinary life, but, in such a case, the conditions are unhealthy, and to a person entering from the open air the room will feel close and stuffy. The supply of fresh air to any room ought to be such that the percentage of carbon dioxide is kept below 0·06.

Now, it is estimated that a man, breathing quietly, gives off 0·06 cubic feet of carbon dioxide in an hour. Suppose one man in a room containing 1,000 cubic feet of air; this air will contain 0·4 cubic feet of carbon dioxide—that is to say, 0·04 per cent., and in twenty minutes the man will give off 0·2 cubic feet of the same gas (for in an hour he gives off 0·6 cubic feet). Therefore, in twenty minutes the room will contain 0·4 + 0·2 cubic feet of carbon dioxide = 0·6 cubic feet, or 0·06 per cent. Thus in twenty minutes the air will have reached the border line between purity and impurity, and ought to be renewed. *One man, therefore, needs 1,000 cubic feet of air every twenty minutes, or 3,000 cubic feet every hour.*

A crowded room will naturally require more ventilation than a room with few people in it; for instance, four persons in the room considered above would need a fresh supply of air every five minutes instead of every twenty, for they will need 12,000 cubic feet every hour.

This leads us on to another point, which is, that experience has shown that the air in a room cannot be renewed completely more than three times in an hour without causing draughts, and so, discomfort. Therefore

every person should have at least 1,000 cubic feet of room space to himself, and four persons need a room containing at least 4,000 cubic feet. It is quite easy to provide efficient ventilation with a smaller room, but not to provide efficient ventilation, *with comfort*, for fresh air will have to be provided so rapidly that draughts will be produced.

It must be remembered that these figures are ideal, and that, in practice, it is very common to fall far short of them; they represent, however, the standard which should be aimed at.

One of the best, and certainly the simplest, of the methods for estimating the purity of the air in a room is to note the impression produced on a person entering from the fresh air; if he feels the room close and stuffy it is a sure sign that the air has passed the limits of purity, even though those who have been occupying the room notice nothing amiss.

If the windows are closed, and the room crowded, drops of water collect on the window-pane; this is a sign of excessive water vapour, and, though it is not a direct measure of carbon dioxide, it generally accompanies an excess of this, and therefore signifies impurity of the air.

A more definite method of testing the air in a room depends on the fact that if *lime-water* is shaken up with carbon dioxide, it is turned cloudy; a very small amount of carbon dioxide will not do this, but a certain fixed amount of the gas will always affect a certain fixed amount of lime-water. This fact is made use of in a method of calculating the percentage of carbon dioxide in air, known as Angus Smith's method; this needs a number of bottles and some careful calculation, but a simple modification can be performed as follows.

Take a half-litre bottle, with a good stopper, into the room, and fill it with pure water; pour the water out, and the bottle will now contain a 'sample' of the air in the room. Stopper it tightly, and take it to the open air; take out the stopper, and pour in 25 c.c. of clear

lime-water; put in the stopper *at once* and shake the bottle. If the air in the room contains less than 0·06 per cent. carbon dioxide, the lime-water will not turn cloudy.

The same experiment can be performed with a half-pint bottle, and half an ounce of lime-water.

Nitrogen. So far, we have spoken only of the oxygen and carbon dioxide in air, and have said nothing of the nitrogen. Although this forms close on four-fifths of the atmosphere, it does not appear to have any direct action on our lives, but is merely an inert gas which serves to dilute the oxygen; we could not live in an atmosphere of pure oxygen, for the combustion of our tissues would be far too rapid.

Since nitrogen is found in our tissues, it is plain that nitrogen must also be present in our 'intake'; we are not, however, able to obtain this nitrogen direct from the atmosphere, but rely upon that contained in our food.

The **solid particles** in air are of three kinds:

(1) Mineral or metallic particles—*inorganic* matter;
(2) particles derived from the animal or vegetable worlds;
(3) bacteria.
} *organic* matter.

The presence of these solid particles is easily demonstrated by allowing a shaft of bright light to pass into a dark room, when innumerable dancing 'motes' can clearly be seen.

Mineral matter is often present to excess in air which is otherwise very pure; for instance, on a windy day by the sea-shore or on a country heath the air may be full of dust which may give us sore throats or sore eyes though the air itself is quite pure. Mineral matter in air does not, as a rule, do us any permanent harm, though it may be mentioned that in some mines where the air is full of metallic dust the workers suffer from lung diseases directly due to the inspired dust. Mineral matter is, however, often mixed with dead organic matter, and there is no doubt that this is often injurious, though it is very

difficult to obtain any measure either of the extent of the impurity or of the injury which it causes. While speaking of organic matter, it is necessary to say that besides the solid particles air may also contain various *gases* derived from organic sources. The most important is, perhaps, ammonia, which is found to an appreciable extent in the air round large towns, and which is a serious impurity in air; other examples are marsh gas and sulphuretted hydrogen. There are also cases where organic matter in air is specially injurious, though its exact nature may not be known; for example, the air from sewers, or from cesspools or places where putrefaction is going on, is definitely dangerous; also, the organic matter in 'expired' air has something to do with its unhealthiness (see p. 45). In none of these cases, however, do we have an exact knowledge of the nature and cause of the danger.

Bacteria are more frequent in the air of places such as hospitals, especially infectious hospitals, than among healthy people, but they are found practically everywhere and are associated very frequently with other organic matter. It is important to remember that healthy people do not breathe out many bacteria; bacteria are much more likely to be found in a room which is hardly ever occupied and hardly ever ventilated than in a crowded room which is thoroughly well ventilated. A large number of bacteria does not in any way indicate excess of carbon dioxide, nor does excess of carbon dioxide indicate excess of bacteria. Bacteria in the air do not concern us very much practically, unless we are in the neighbourhood of infectious disease, for the vast majority of bacteria are harmless; we do, however, run very frequent risks of breathing bacteria which cause common colds and influenza, and there is also one microbe, very commonly inspired without any suspicion of risk, which gives rise to the widespread and fatal disease of tuberculosis or consumption of the lungs. The methods by which this contamination of the air may be lessened, and so disease be directly prevented, will be discussed in a later chapter.

The blood. The circulation—that is, the method by which the blood is driven round the body—has already been described. Some of the functions of the blood have also been mentioned, but it still remains to describe the nature and composition of the blood itself.

Blood, as every one knows, is a red, non-transparent, rather sticky fluid. A proper examination shows, however, that it is not a simple red liquid, but is in reality composed of a *slightly yellow liquid, the plasma, containing in suspension a vast number of solid bodies, the corpuscles.* These corpuscles are of two kinds, the red and the white, the red outnumbering the white by about 500 to 1. It is the presence of the red corpuscles that gives the blood its red colour. The corpuscles are obviously very minute, for, to the naked eye, they are quite invisible, but they can readily be seen under a microscope. The *red corpuscles* have a definite shape, having the appearance of minute round disks slightly hollowed out on each surface ; seen singly they are yellowish red, but in numbers they give a vivid red colour ; their diameter is about $\frac{1}{3200}$ of an inch ($\frac{1}{150}$ of a millimetre). Now the diameter of a fine capillary is about $\frac{1}{3000}$ of an inch, so that clearly a red corpuscle will often have a tight fit to pass through a capillary ; the corpuscles are, however, elastic, and can be squeezed round corners and past obstructions, and, when past, will recover their former definite shape. The red corpuscles are very apt to form columns like piles of counters.

The *white corpuscles* are slightly larger than the red, and, as stated above, are far less numerous, so that they have no effect upon the appearance of the blood. They have the simple appearance of small lumps of clear jelly, containing granules of darker material ; they are constantly changing their shape and are not elastic like the red corpuscles—that is to say, they are readily squeezed past obstructions but they do not afterwards return to any definite shape.

When blood is drawn from the body and allowed to

stand in a vessel it is found to lose its fluid condition and become jelly-like in consistence : so firm, in fact, does it become, and so closely does it stick to the side of the vessel, that it will not fall out if the vessel be turned upside down.

This process, which begins in about two minutes and is complete in about ten, is known as the *clotting* or *coagulation* of the blood, and it may be mentioned here that it is because the blood clots that we do not bleed to death from any trivial scratch ; if the blood remained fluid it

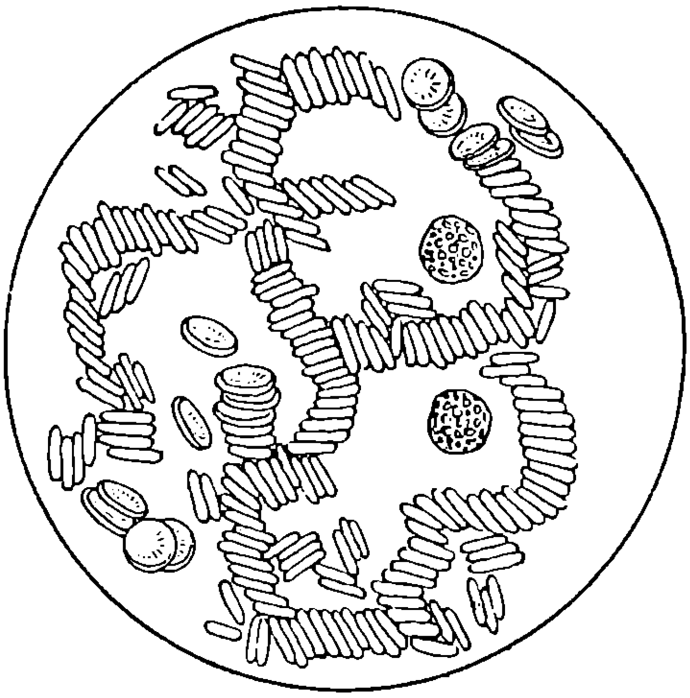

FIG. 9. Red and white corpuscles.

would continue to escape from any wound of the circulation, and it only does not do so because a clot forms which effectively seals up the opening in the vessel.

If the clot is allowed to stand still further, drops of a light yellowish liquid are seen to exude from the dark red mass, and the mass itself begins to shrink ; this continues till, in the course of a few hours, the dark-red clot is lying loose in the liquid.

The process of clotting may be shortly described as follows ; it will be found to have some resemblance to a process which occurs in milk and which will be described in due course.

The plasma contains a substance which, after the blood is shed, is converted into a network of stringy material known as *fibrin*. The network is so complete that it holds in place every corpuscle and makes the whole mass of the blood jelly-like in consistence. Soon the network begins to contract; its meshes are too fine for the corpuscles to escape, but the liquid part of the blood can do so, and, consequently, this is squeezed out so that the clot eventually consists of nothing but fibrin and corpuscles. Now a little consideration will show that the squeezed-out liquid, which is known as *serum*, is simply *plasma minus fibrin*. Serum and plasma, with this one exception, are similar in their constitution.

Pure plasma can be obtained by the use of some method, of which there are several which need not be described here, of preventing the blood from clotting. If blood, which has been treated in one of these ways, is allowed to stand in a tall vessel, the corpuscles, which are heavier than the plasma, will gradually sink.

In course of time the following appearance will be seen—a solid dark-red column of red corpuscles in the lower two-fifths of the vessel, and nearly colourless plasma in the upper three-fifths. On the top of the red corpuscles there is a thin whitish film of white corpuscles, these being somewhat lighter than the red. It is important to remember this method of obtaining plasma, because it shows very clearly the constitution of the blood—that it is not a simple red liquid, but is a nearly colourless liquid, with red solid corpuscles in suspension.

Some idea of the smallness and closeness of the corpuscles can be gathered from the fact that one cubic millimetre of blood contains about 5,000,000 corpuscles.

So much for the constitution of the blood; let us now consider the composition and functions of the various parts.

The **plasma,** the fluid part of the blood, consists of water holding various substances in solution. Some clue to the nature of these substances is obtained by

considering the functions of the plasma; these are to absorb digested food, to carry this away to the tissues, and to carry away from the tissues the waste products which result from their oxidation. It is clear, then, that the subject will be understood better when food, digestion and absorption, and excretion have been studied. For the present it is sufficient to say that the plasma contains in solution

(*a*) *Proteins.* These are very complex bodies, and are the most important and complete parts of all living matter. Of the proteins in the plasma the chief are
  (1) *Albumin* and
  (2) *Globulin,* which are found in all the tissues of the body.
  (3) *Fibrin*—the clot-forming substance—which is peculiar to the blood itself.

(*b*) *Salts,* of which the most abundant is sodium chloride.

(*c*) A small trace of *sugar.*

(*d*) A small quantity of *urea,* which is a product of excretion.

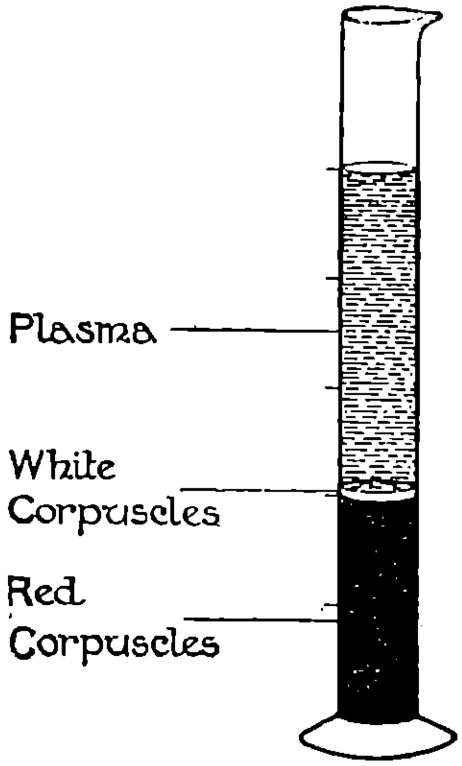

Fig. 10. Plasma and corpuscles in non-clotting blood.

The plasma also contains, after meals, a small quantity of *fat.* This, however, is not dissolved, but is suspended in the shape of exceedingly fine globules.

Besides acting as a carrier, the plasma shares with the **white corpuscles** the very important functions of (i) resisting invading bacteria and (ii) repairing wounds, and removing inflammation. The plasma and white corpuscles are, in short, important factors in our 'immunity'. The exact parts that each play are not yet exactly known, but it is probable that they both aid in killing germs, and that the white corpuscles afterwards absorb them.

This much is certain—that, when the body is wounded, the white corpuscles crowd to the wounded part, and here have a double function: (i) to resist any bacteria which may gain access, and (ii) to help to repair the wound. It is equally certain that, without a healthy and efficient plasma, the white corpuscles cannot do very much by themselves.

The **red corpuscles** owe their colour to the presence of a substance known as *haemoglobin.* This, like the albumin and fibrin in the plasma, is a protein, but it is peculiar in the fact that it contains a little *iron.* The red corpuscles have a very important function, for they act as *oxygen carriers.* The haemoglobin which they contain has the power of combining loosely with oxygen; in the capillaries of the lungs the haemoglobin rapidly takes up oxygen from the air, and in the capillaries of the body it gives up oxygen to the tissues. When fully combined with oxygen haemoglobin is a bright scarlet, but when it has parted with its oxygen to the tissues, it is distinctly darker: this explains why the blood in the veins is darker than that in the arteries.

Besides these separate functions of the various parts of the blood, the blood as a whole is of use in keeping the temperature of the various parts of the body even. If one part of the body were in active exercise, and another part still, the former would become much the hotter were it not for the circulation of the blood, but this by its constant passage all over the body maintains a constant temperature in all parts. Further, if the whole body becomes hot, the blood-vessels in the skin dilate so that heat may be given off to the surrounding air as quickly as possible; if the body be cold the skin vessels constrict so that as little heat as possible is lost.

CHAPTER IV

CLIMATE

In the last chapter the composition of the atmosphere was described, and the various substances contained in it were discussed. In the present chapter we have to consider the atmosphere as a whole, and the effects which its varying conditions produce upon the **climate** of different parts of the earth.

The climate of a place depends upon the following factors :

(1) Temperature of the air.
(2) Movement of the air (winds).
(3) Humidity of the air.
(4) Sunshine and rainfall.

All these, it is obvious, must react upon each other, but all are factors that have to be considered in describing a climate. From year to year the climate of any part of the earth may be foretold with considerable accuracy, from previous observations : but from day to day it is found that all the above atmospheric conditions vary with another condition known as (5) the pressure of the air.

The climate of countries is also affected by such conditions as proximity to the sea and relation to ocean currents, relation and distribution of mountain ranges, and, in a lesser degree, of forests, and the direction of prevailing winds.

In addition, the **latitude** of any place is of immense importance if the surface of the globe were level and uniform, instead of being broken up into land and sea, valleys, plains and mountains, the climate of any part of the earth would entirely depend upon its latitude

(or distance from the equator) we shall find, however, that places of the same latitude may have very different climates, though it is still true, speaking generally, that the nearer we get to the equator the hotter is the climate, and vice versa. The varying nature of atmospheric conditions cannot be understood without a knowledge of the meaning of the expression 'pressure of the air', or

Atmospheric pressure. In the first place it is most important to realize that air has *weight*: it is not a mere 'nothingness', but, as we know, is a mixture of definite substances and so must have a definite weight of its own.

Secondly, air (or any other gas, or mixture of gases) will contract or expand under different conditions, or, to put it in rather more scientific language, 'a given *mass* (or weight) of air will occupy a different *volume* (or amount of space) under different conditions.'

Two of these conditions are those of *pressure* and *temperature*. Suppose A (Fig. 11) to be a cylinder containing air, and B to be a piston whose fitting into A is absolutely *airtight*. Pressure exerted upon B will drive it a little further into A.

The original mass of air will now occupy a smaller volume, and the air itself will be *denser* and *heavier, bulk for bulk*. If the pressure be now removed the piston will return to its former position, and the air will again occupy its original volume. Those who remember the description of the 'elasticity' of muscle, will understand that air, also, must be elastic, for it has returned to its original state when placed under its original conditions.

If the piston be now pulled, it will, if the pull be strong, be moved a little way further out of A: the air now occupies a greater volume, and is more *rarefied* and *lighter, bulk for bulk,* than before. When the pull is stopped the piston will return to its original position once more.

If this experiment were being actually performed, it would be found that very considerable force would be required to move the piston: this again illustrates the

elasticity of air, for an elastic body is always *trying* to keep its original condition, and, consequently, resists any force which tends to alter it. We may say, then,

(1) Increased pressure decreases the volume and increases the density of air.

(2) Decreased pressure increases the volume and decreases the density of air.

Temperature affects air in a converse manner, for heated air expands and becomes more rarefied than cold air.

Increased temperature, therefore, has the same effect upon the volume and density of air as *decreased pressure*, and vice versa.

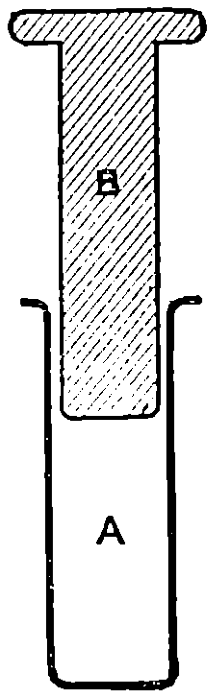

FIG. 11. Piston and cylinder of air.

Let us now consider the conditions which result from the presence of the atmosphere over a definite patch of ground, say one square yard. There is a great column of air reaching right to the limits of the atmosphere, one square yard in cross section, resting upon this square yard of the earth. Consequently, since air has weight, there is a definite weight or pressure of air upon the ground ; near to the ground the air is under the same pressure as the ground itself, but as we go higher the column of air above us becomes steadily shorter, and, therefore, the pressure due to this column becomes steadily less: in other words the higher we go the more rarefied does the air become, and vice versa.

This fact is of very great importance because it is plain that in rarefied air there is a smaller *quantity* of oxygen (though not a smaller percentage) this explains why it is that people who go to Switzerland and at once climb high mountains suffer from what is called 'mountain sickness' if they are careful to get into good 'training' first, they suffer far less inconvenience : the significance of 'training' we shall consider later, but training only increases the height to which people can go without discomfort, for sooner or later discomfort is sure to occur,

and this is due to the diminished quantity and pressure of oxygen in the air: in balloons, where no exertion is required, men can go to a greater height, but they also will suffer eventually and there have been many cases of unconsciousness, and even death, resulting from too great an altitude being reached.

In the depths of mines the air is under greater pressure, and is more dense: here, however, perfect ventilation is very difficult to attain, and, consequently, though there is plenty of oxygen, the pressure of impure gases makes the air in mines less healthy than the open air above.

It should be clear that as we get very high the air becomes very rarefied indeed and gradually fades away into the emptiness of space. The exact limits of the atmosphere are, therefore, very difficult to calculate, but, knowing the weight of air and the pressure the atmosphere exerts, we are able to say that *if* all the atmosphere were of the same density as that at sea level the thickness of the atmosphere would be about five miles: actually, it is vastly greater than this. The actual pressure of the atmosphere is measured by the instrument known as the **barometer:** the best way to describe a barometer is to describe a simple method of making one.

The apparatus needed is (1) a glass tube about 36 inches long, and half an inch (or rather less) across, closed at one end and open at the other, and (2) a bowl, three or four inches deep, containing mercury (quicksilver). Both tube and bowl must be absolutely clean.

Fill the tube completely with mercury, and put the thumb over the open end: turn the tube upside down, holding the thumb tightly over the open end so that no mercury can run out, and bring this open end (the tube being vertical) well under the surface of the mercury in the bowl. Now remove the thumb, and at once the mercury in the tube drops a few inches so that the column of mercury, measured from the surface in the bowl to the surface in the tube, is about 30 inches high. If the

tube were 60 inches long the mercury would drop about 30 inches; if it were under 30 inches long the mercury would not drop at all; about 36 inches is chosen as the length of the tube simply for convenience.

Now let us consider what this dropping of the mercury means. In the first place we must realize that the space at the top of the tube contains *not air, but nothing*: it is what is known as a *vacuum*, so that the mercury in the tube is quite free to move if any force tends to push it up or down. Inside the tube we have a column of mercury about 30 inches high trying to flow (because of its weight) into the mercury in the bowl: outside we have the pressure of the atmosphere pressing upon the mercury in the bowl, and *it is this pressure which keeps the mercury inside the tube*: in other words the pressure of the atmosphere outside the tube *balances* the pressure of the column of mercury inside. If, for any reason, the atmospheric pressure becomes greater a little more mercury is driven into the tube and the column rises: if it becomes less a little mercury escapes.

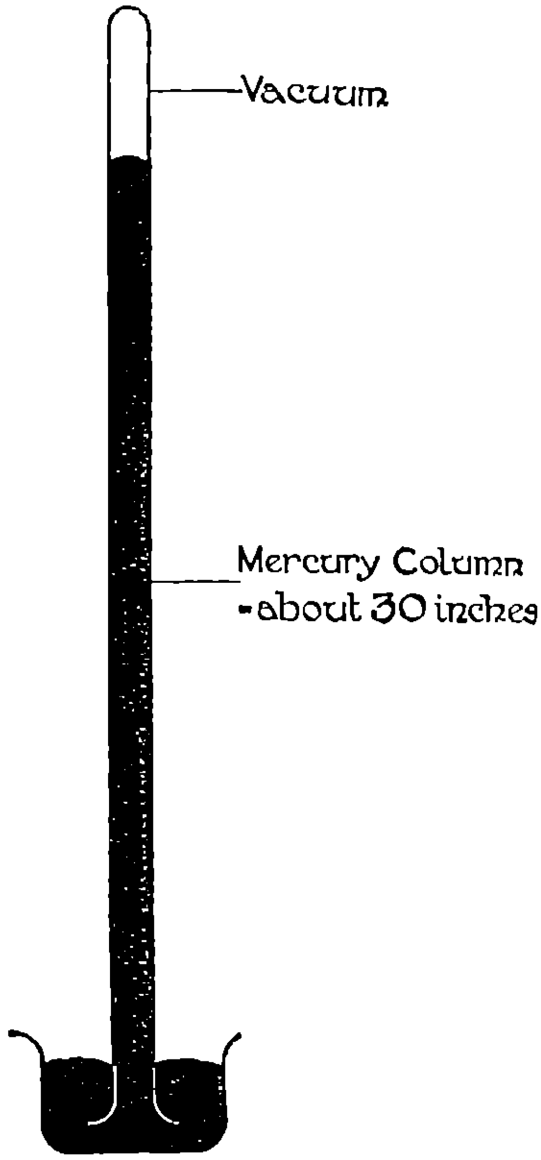

FIG. 12. Tube and bowl barometer.

It is very important to remember that the lower limit of the column is measured from the mercury in the bowl, and not from the bottom of the tube. By holding the tube upright in a stand, and by putting a scale alongside we could measure the height of the column, and so measure any alterations in atmospheric pressure by noting any changes in the height of the column.

Accurate barometers are usually made on the above *principle*, but

(1) they are very carefully constructed ;

(2) they are fitted with apparatus by which the measurements may be very accurately read off.

In Fortin's barometer, for instance, the bottom of the bowl or cistern is made of leather, and rests upon a screw. It can, therefore, be moved up or down, by means of the screw, till the surface of the mercury just touches a fixed ivory point. The surface of the mercury in the bowl is, therefore, always at the same point on the scale, and the top of the column can be simply read off against the scale.

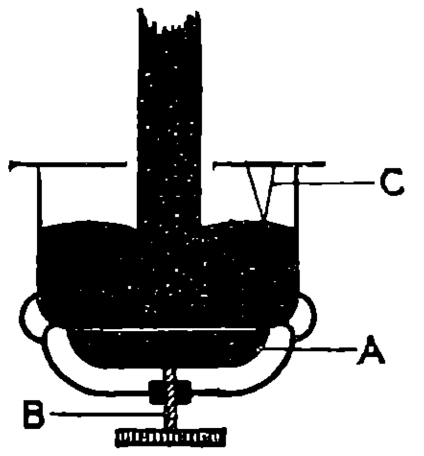

FIG. 13. Diagram of Fortin's barometer. A, Leather bottom of mercury bowl, resting on B, a screw; C, Ivory point.

The scale is further provided with an apparatus known as a 'vernier', so that the smallest fraction of an inch may be measured.

When the reading has been accurately taken, various 'corrections' have to be made, for strict accuracy, of which we must mention two.

(i) *Temperature.* Mercury, like air, expands when heated. The same weight of mercury will therefore fill a somewhat longer column on a hot day than on a cold, and allowance must be made for temperature. It is customary to consider freezing-point as the 'standard' temperature.

(ii) *Altitude.* It should be clear that the barometer will give lower readings in the hills than in places at sea level. The sea level is the 'standard' level, and if a barometer is used for scientific observations, the altitude of its situation must be known so that the necessary corrections may be made. It is found that a height of 1,000 feet makes a difference of about 1 inch in the height of the mercury.

Conversely, it is clear that if one climbs a mountain

with a portable barometer, a rough estimate of the height reached can be obtained. *Siphon* barometers are sometimes used: in these, the glass tube is made so that the open end turns upwards, instead of dipping under mercury in a bowl. The reading is taken between the two surfaces of mercury in the two limbs of the tube.

Glycerine barometers. A barometer can be constructed with glycerine instead of mercury: glycerine is, however, a far lighter substance, and the tube must be over 27 feet in length, instead of 3 feet. Such an instrument is, of course, hopelessly inconvenient for ordinary use: it has, however, one advantage over mercury in that changes of atmospheric pressure produce greater alterations in the glycerine column than in the mercury: it is, in fact, more 'sensitive' than mercury.

Aneroid barometers are constructed on a different principle: a small air-tight metal box has the air pumped out of it, so that when the pressure outside is great, the top of the box is forced a little in, and when the pressure is small it returns a little out: this movement in the box is magnified by levers, and communicated to a hand on a dial, on which the various degrees of pressure are marked: every aneroid barometer must be carefully 'graduated' by comparison with a mercury barometer, and the right places for the figures on the dial found in this way. An aneroid can never be quite so accurate as a good mercury barometer, but a well-made instrument is very reliable and very convenient.

The pressure of the air at any place is constantly changing for a variety of reasons, but is rarely more than 31 inches of mercury, or less than 28, at sea level. The barometer is commonly known as 'the glass': every one is familiar with the expressions 'The glass is rising' or 'steady' or 'falling', and knows that by consulting the barometer some estimate can be formed of what weather to expect. Many mercury barometers are fitted with dials similar to those of aneroids, on which, opposite the various pressures, are written the words Set Fair,

Changeable, Very Wet, &c. the hand on the dial is moved by the changes in the column of mercury, and is intended to give not only the actual pressure of the air, but also some indication of the weather to be expected.

We shall learn in some of the later paragraphs of this chapter why it is that the weather is apt to vary with the rise and fall of the barometer.

We may now proceed to discuss the various factors which produce differences in climate.

The **temperature,** or degree of warmth of any part of the earth, depends ultimately on the amount of heat derived from the sun. This reaches us in two ways :

(i) **Radiation.** The heat rays from the sun travel through the air, and heat the surface of the earth directly. The air itself is only slightly warmed, but the water vapour in the air intercepts and absorbs much of the heat of the sun's rays, and prevents them from being too overpowering. The sun's rays, as is well known, cannot effectively penetrate a thick cloud. Radiation is more powerful at the equator, where the sun is vertically overhead, than in temperate zones, where it is never vertical and the rays have to pass obliquely through the atmosphere. The sun's rays may be very warm, even when the air is very cold. Sir Ernest Shackleton says in one passage of his book *The Heart of the Antarctic* : 'The sun beat down on our heads and we perspired freely, though we were working only in shirts and pyjama trousers, while our feet were cold in the snow.' This was written during the dash for the south pole, where the whole country was perpetual snow and ice, and the cold intense if the sun went in. On the tops of high peaks also, if the air be still, the sun may be uncomfortably hot though snow is perpetual.

In tropical countries those who are not used to a vertical sun have to take the greatest care not to expose themselves freely to the sun's rays. Sunstroke rapidly follows, unless proper protection is afforded to the head and, almost equally important, the back of the neck.

(ii) **Convection.** This depends upon the fact, previously mentioned, that heated air expands and becomes more rarefied than cold air. The land is heated by the sun's rays, and, in its turn, heats the air beside it: owing to its lightness this air rises and cold air from above falls to take its place, and is heated by the ground in its turn. Thus currents are set up, and the air is gradually warmed, the air nearer the ground being always the warmer: these currents are known as 'convection' currents. The ground absorbs much of the heat which it obtains from the sun's rays (though it radiates some away again), and, consequently, the process of heating the air by convection goes on after the sun has set. The ground, however, cools very rapidly, and before long becomes colder than the air: the air then becomes gradually cooler: convection currents, obviously, do not play the same part in the cooling of the air, for the air cooled by the ground does not tend to rise. The net result is that the air approaches much more to a uniform temperature than does the ground.

From these considerations it is plain that to obtain the true average temperature of a place proper precautions must be taken. Thermometers are used to measure temperature, and 'shade' thermometers and 'sun' or 'radiation' thermometers are necessary. The shade thermometers are placed about 4 feet from the ground in small boxes which are open to the air, but are so arranged as to shelter the thermometers both from the radiations of the sun and from those reflected from the ground. Sun thermometers have their bulbs blackened so as to absorb the sun's radiations as fully as possible, and are, of course, open to the sun's rays; they, too, are placed about 4 feet from the ground, but there is also needed another thermometer placed on a small stand close to the ground which can record the lowest temperature the ground reaches. The shade thermometers can be so constructed that they will record both the 'maximum' and the 'minimum' temperatures reached during the day; the sun thermo-

meter need only show the maximum and the ground thermometer the minimum.

Averages of the 'shade' readings during the day will give the average temperature of the air, and averages of the sun and ground thermometers that of the ground.

Temperature is, on the whole, the most important of all the factors which go to make up a climate, especially from the point of view of hygiene, but it is very dependent on, and greatly complicated by, the other factors which we must now discuss. Also it is a matter of common observation that days with the lowest temperature are not necessarily the days which *feel* the coldest: on a still day, with many degrees of frost, we do not feel so cold as on a day when a strong dry wind is blowing, with the thermometer, perhaps, twenty degrees higher. The reason for this we shall see later.

Motion of the air. Winds are very complex in their origin, but they are primarily due to differences in temperature in different parts of the earth, and are thus convection currents on a large scale. The air over the hottest portion of the earth, the equatorial region, is constantly tending to rise, and the cooler air from the temperate regions flows in to take its place. There is, therefore, in the lower regions of the atmosphere north and south of the equator a current flowing from poles to equator, and in the higher regions a current flowing from equator to poles. The higher currents steadily cool down and become denser and tend to fall, so that, later, they are felt as *low* currents passing from equator to poles. This suggests that there must be well-defined belts somewhere between the poles and the equator from each side of which currents of air flow out, and that at these points there must be a certain 'heaping up' of the atmosphere. Heaping up of the atmosphere will mean *increased pressure*, and barometric observations show that there are, in actual fact, definite belts of increased pressure running about the level of latitude 30° north and south. A little consideration will show that where we

get a heaping up of the atmosphere winds must flow to where there is less air : in other words *wind flows from regions of high pressure to regions of low pressure.* While all motion of the air is primarily due to changes of temperature, winds are more directly due to differences of pressure. The less the distance between a high-pressure region and a low-pressure region, or in more scientific words 'the steeper the pressure gradient', the greater will be the velocity of the wind. These winds will be felt *at low levels,* but it is of great importance to remember that the currents at different levels of the atmosphere do not all travel in the same direction. In great volcanic eruptions, such as those of Krakatoa in 1883, it has been noted that the bulk of the dust and vapour from the mountain is carried in one particular direction : some, however, which has been expelled with great force to high altitudes, has been clearly seen to travel in a precisely opposite direction. This may also be noted, on more ordinary occasions, by observing the direction of travel of low-lying and high-lying clouds. The fact is also particularly clear to balloonists, who have to go where the currents of air take them.

It is, however, the lower currents—that is, *the currents which we feel*—that particularly concern us, and these are chiefly determined by the great belts of high pressure at latitude 30° north and south. On the polar side of these belts the lower currents flow towards the poles, and on the equatorial side to the equator ; at the belts themselves and also at the equator there are regions of comparative calm. *If the earth were still,* and *if the surface of the earth were uniform,* these winds would flow due north and south.

Let us first consider the result of the fact that the earth revolves from west to east, remembering always that where the earth revolves the atmosphere revolves with it.

Winds flowing *to the equator* are passing to more quickly moving parts of the earth, and, therefore, are felt in the

face of a man looking in the direction of the earth's travelling; in other words they appear to come from the north-east in the northern hemisphere, and the south-east in the southern hemisphere, and not from due north and south. Winds travelling towards the poles are travelling to more slowly moving parts of the earth and seem, so to speak, to be catching it up; they appear, therefore, to come from the south-west in the northern hemisphere and from the north-west in the southern.

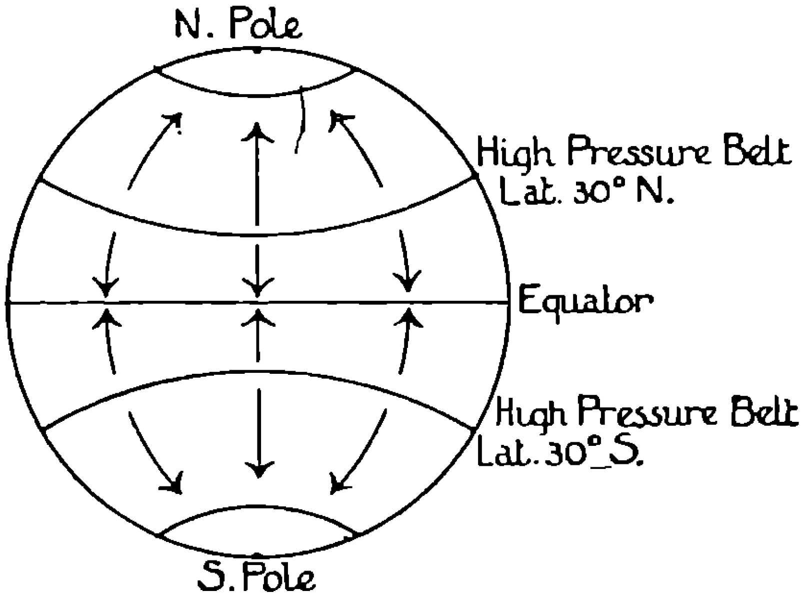

Fig. 14. Diagram of winds which would be produced by the unequal heating if the earth were both still and uniform.

Some careful consideration of the diagrams will help to make the point clear.

The winds are also profoundly modified by the fact that the surface of the earth is not uniform, but is broken up into land and sea, while the land masses are further broken up by the presence of mountain ranges. The winds are, therefore, not uniform in any part of the earth, but they are far more uniform in the low latitudes, near the equator, than in the high latitudes. In the former regions they are known to seamen as the *north-east and south-east 'trades'*, and are counted upon, as a matter of course, by sailing ships in these parts. In high latitudes, however, the modifications are so great that we can only say that the *prevailing winds* are south-west or north-west,

as the case may be, and they can never be counted on from day to day.

These modifications of the winds produce the cyclones and anticyclones to be described shortly. The calm region at the equator, between the 'trades', is known as the 'Doldrums', and here ships are apt to be becalmed; in all calm regions winds of local origin may spring up, and irregular squally storms are not uncommon in the Doldrums. The belt of calm, or, at any rate, of light

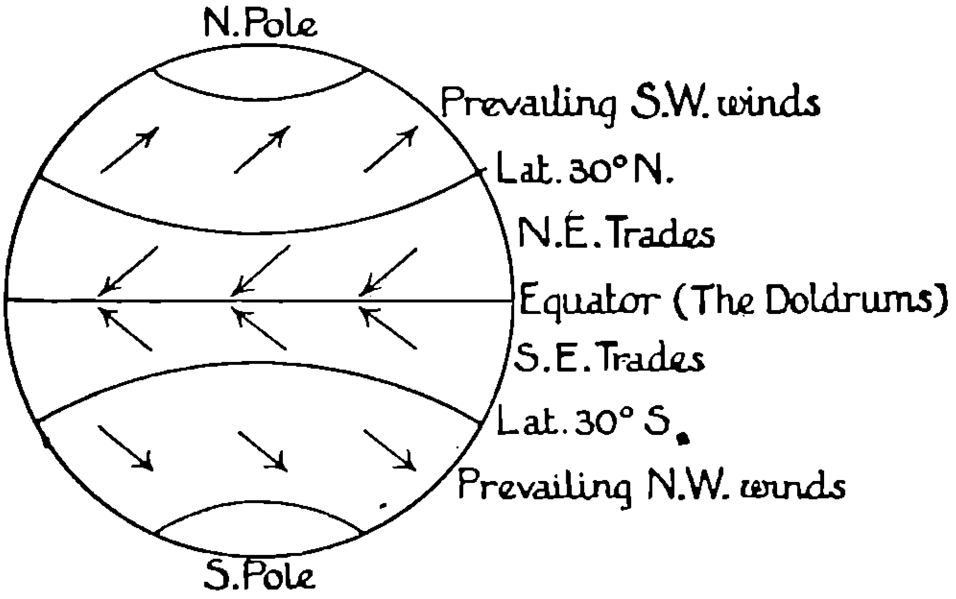

FIG. 15. Diagram to show alteration in winds produced by the rotation of the earth. If the earth were uniform, the directions of the winds would be constant; since it is not uniform, they are only the prevailing directions.

variable winds beyond the trades, is known as the 'Horse' latitudes.

Barometric observations are constantly being taken all over the world, and thus different areas of low pressure, or of high pressure, are noted: these *areas of pressure* are, of course, always altering in their relations to each other, but they tend to take up definite shapes. The commonest forms of pressure areas are *cyclones* and *anticyclones.* In cyclones, which are low-pressure areas, the lowest pressure of all is in the centre: in anticyclones, or high-pressure areas, the highest pressure is in the centre. It is clear, then, that in the first case wind will tend to blow towards the centre, and in the second from the centre. In neither

case does the wind blow directly to or from the centre, but always blows spirally : we may say, then, that in cyclones the wind blows spirally inward and in anticyclones spirally outward. In the northern hemisphere the winds in anticyclones follow the hands of a watch, and in cyclones are in the reversed direction. The direction of the winds in cyclonic and anticyclonic areas can be remembered

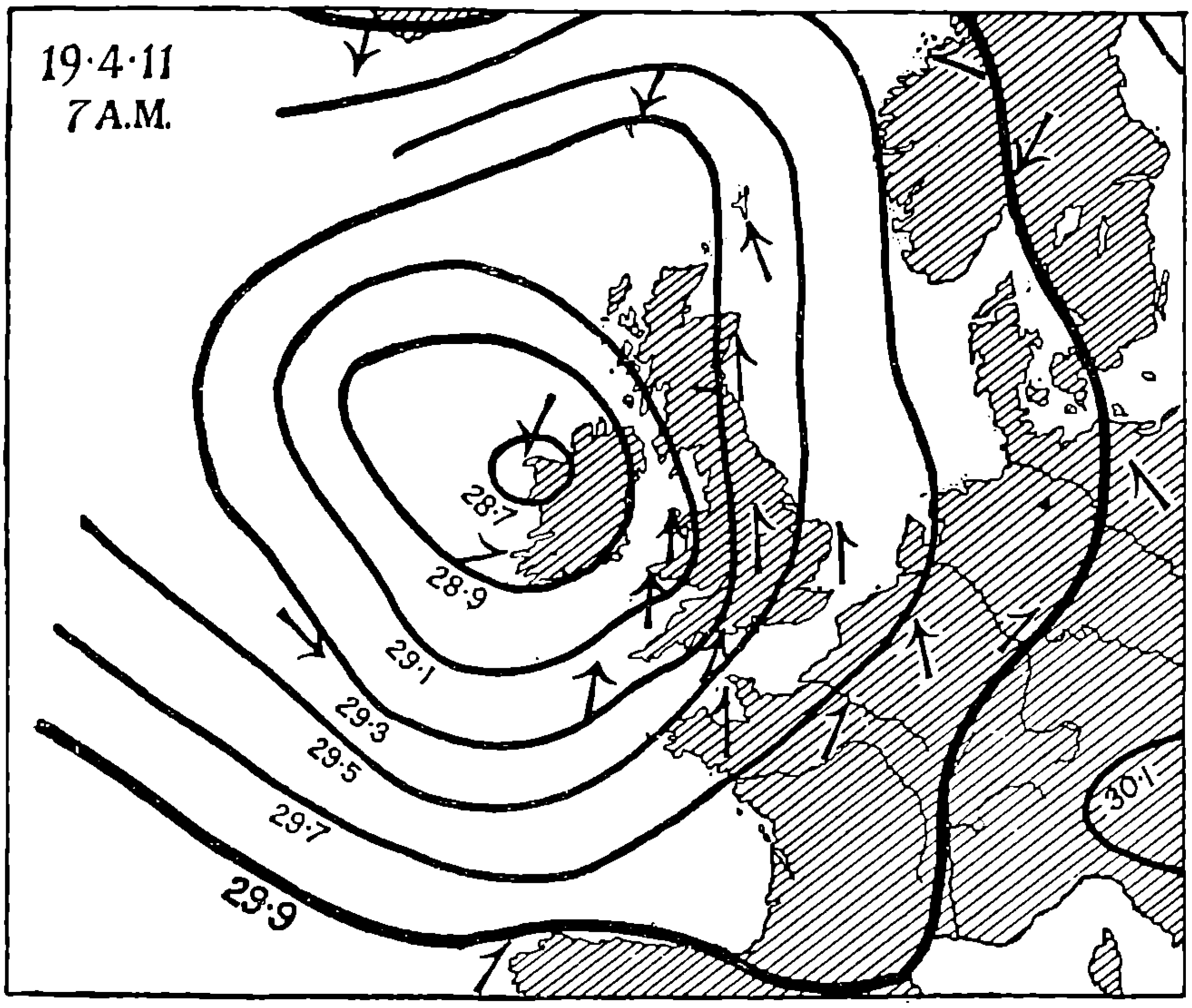

Fig. 16. Low-pressure system or cyclone.

by the use of *Buys Ballot's* law, which states that a man who stands with his back to the wind always has lower pressure to his left and higher pressure to his right. Cyclones travel bodily along in an eastward direction : anticyclones remain much more stationary and are usually much larger. Both cyclones and anticyclones are liable to break up from time to time and form fresh arrangements of areas of pressure. The diagrams bring out another fact, which is that at the two opposite edges of a cyclone

or anticyclone the wind will be in exactly opposite directions. The most striking example of this fact is that given by the winds known as the 'Roaring Forties': there is apt to be a succession of cyclones in the South Atlantic, with their northern limits somewhere about latitude 40–2°, and their southern limits about latitude 45–6°. Along the northern limit the winds will be

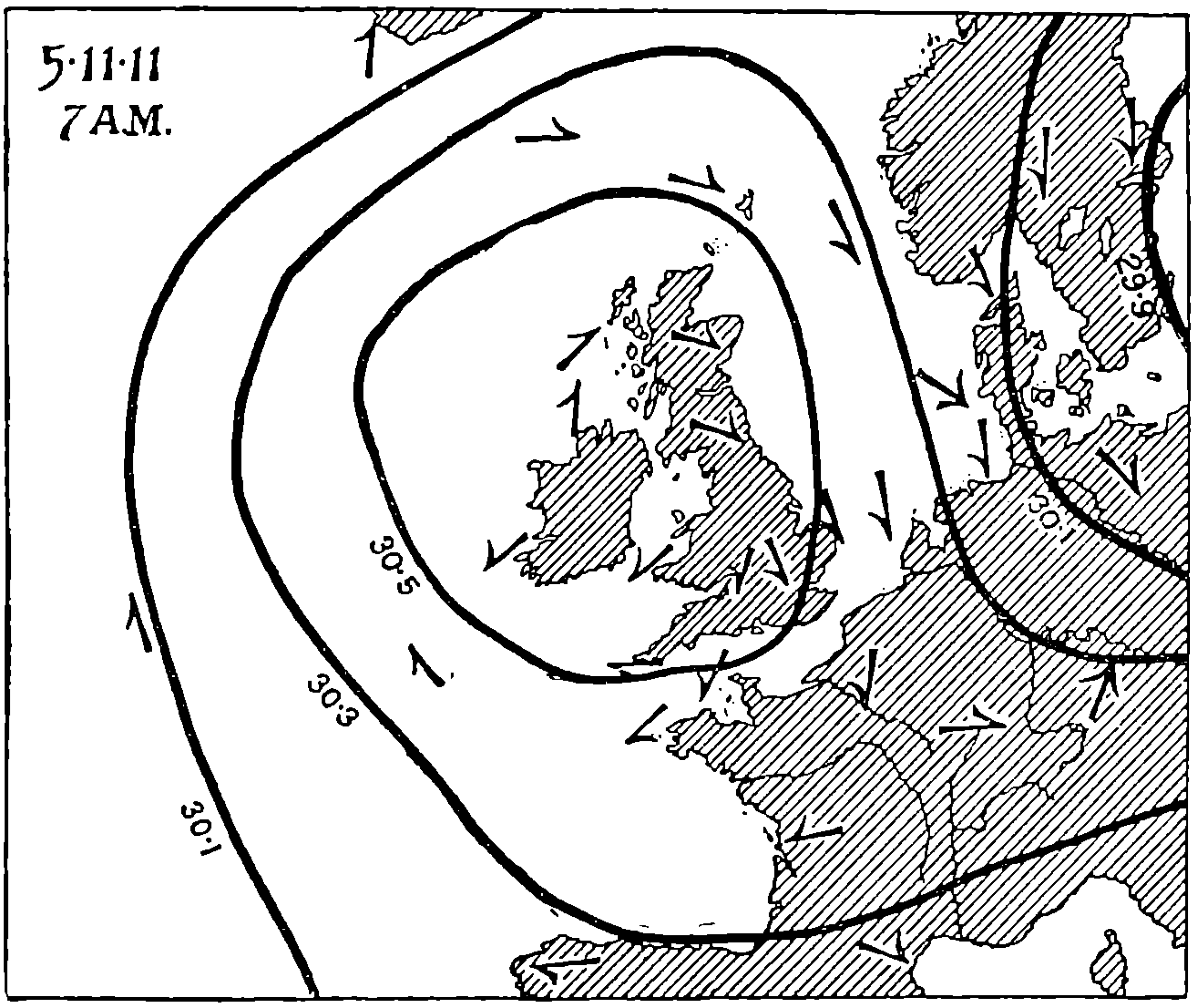

FIG. 17. High-pressure system or anticyclone.

westerly, and ships bound from Cape Colony to Australia keep about latitude 40°, where they expect a following wind: ships returning keep about 5° further south. It will be noticed that these cyclones are about 300 miles across.

Advancing cyclones (attended by a falling glass) are associated with rain, clouds, and a moist and dull atmosphere with variable winds they pass over, and may leave behind them sunshine and clear air, but they are

liable to be closely followed by fresh cyclones at their heels. Anticyclones (and a rising glass) signify the approach of dry clear air, sunshine and blue sky with light winds : they are much more lasting in their effects since they are more stationary, and may mean continued fine weather. They may cover an area extending over thousands of miles. They leave bad weather behind them when they break up or pass away.

The variations in the regular polar and equatorial winds are due to the differences between land and sea temperatures, which will be described more fully later. The most typical of these on a grand scale are the *Monsoons* which are found in the Arabian Gulf and the Indian Ocean. In the summer a south-west monsoon blows over these seas to sweep over the great heated land masses of Southern Asia : in the winter, when the sea is warmer than the land, the north-east monsoon blows in the opposite direction. The transition from one monsoon to the other is not abrupt, but may take six weeks : during this period, in the same way as in the calm belts, such as the Doldrums, local winds may spring up and excessive hurricanes are frequent between the monsoons. These hurricanes, known as typhoons, tornadoes, cyclones, &c., in different parts of the world, are cyclonic in their nature, but they produce violent winds because they are comparatively small in area : reference to the diagrams will make it clear that if the area is small the 'pressure gradient' will be steep, and therefore the winds will be violent.

Winds exercise a very marked influence upon climate. In the first place they may come from cold and dry places and so tend to produce a cold dry climate, or, on the other hand, they may be moisture-laden, when they will tend to produce rainfall. Again, the mere fact that the air is in motion will produce an effect upon the dryness or moistness of the atmosphere : the reasons for this will be more clear when we have discussed the humidity of the air : for the present we will merely say that *motion of the*

air favours evaporation. We shall also see that this is the reason for the fact mentioned when we were dealing with temperature, namely that we feel much colder on a windy than on a still day.

Humidity of the air. It has already been mentioned that air contains a varying amount of water vapour, and that this water vapour is of great importance in that it intercepts and absorbs much of the heat of the sun's rays. Similarly, it intercepts much of the heat which is reflected and radiated back from the earth's surface. This heat would otherwise travel into space and be lost to the earth, so that the water vapour in the air prevents both too great a provision of heat *to* the earth and too great a loss of heat *from* the earth.

Only a certain amount of water vapour can exist in a given space, whether there be air in the space or not, and this amount varies with the temperature; when it is hot there can be far more water vapour than when it is cold. Air which contains the maximum possible of water vapour is said to be *saturated*: if an attempt is made to increase the amount of water vapour, the extra amount will condense at once to form actual particles of water; the same result must be produced if air is cooled, since cold air can contain less vapour than hot: sooner or later a point will be reached when the air will be saturated, and as soon as the temperature is lowered beyond this point drops of moisture will form. The temperature at which the air is exactly saturated is known as the **dew point**; for it is at this temperature that moisture begins to appear or, in other words, that dew begins to be deposited. The 'dew point' will vary from day to day, according to the amount of water vapour in the air: if there is much water vapour, the dew point will be higher.

This condensation of moisture is very common in everyday life, and there are two great constant examples. The air in the higher levels of the atmosphere is far colder than the air in the lower levels, and consequently cannot hold so much water vapour: when air rises to

higher levels, the saturation temperature is often reached, and the vapour condenses to form clouds which will later fall as rain. Similarly, after sunset, the ground cools down quickly, and it is very common to find water deposited as dew as soon as the air near the ground has become sufficiently cooled to be saturated. A little consideration will make it clear that dew is most likely to appear after a fine sunny day followed by a cold night: the sun's heat, throughout the day, has been evaporating water from the earth's surface, and the air, consequently, contains a great deal of vapour: the rapid cooling of the ground after such a day will soon cause a big deposit of dew.

If the air at any time is saturated with moisture, the dew point will be the same as the actual temperature of the air: as a general rule, however, the dew point will be below the air temperature.

The dew point may be determined by direct or indirect methods. In the direct methods the apparatus is so contrived that the temperature of the air in the neighbourhood of the bulb of a thermometer is rapidly lowered: this bulb is blackened or silvered so that drops of moisture can be easily seen. As soon as the air has reached saturation point drops of moisture appear on the bulb, and the temperature is at once read off: the cooling process is now stopped, and the temperature slowly rises then comes a point where the drops of moisture disappear, and the thermometer is again read. The mean point between these two readings (which should be very near to each other) is taken as the 'dew point'. It is by no means easy to be exactly accurate with these direct methods, and indirect methods are commonly used, the instrument employed being known as the *wet and dry bulb thermometer*. In this instrument two thermometers are placed side by side on a stand: the bulb of one is covered by a piece of muslin which hangs down and dips into a small vessel of water. If the air is saturated with water vapour, there is no evaporation from the muslin; but if the air is *not*

saturated, evaporation takes place and, as a result, the temperature of the muslin-covered thermometer is lowered. The temperature soon becomes constant, and the two thermometers are now read off: by this means we obtain *the dry bulb temperature* and *the wet bulb temperature.*

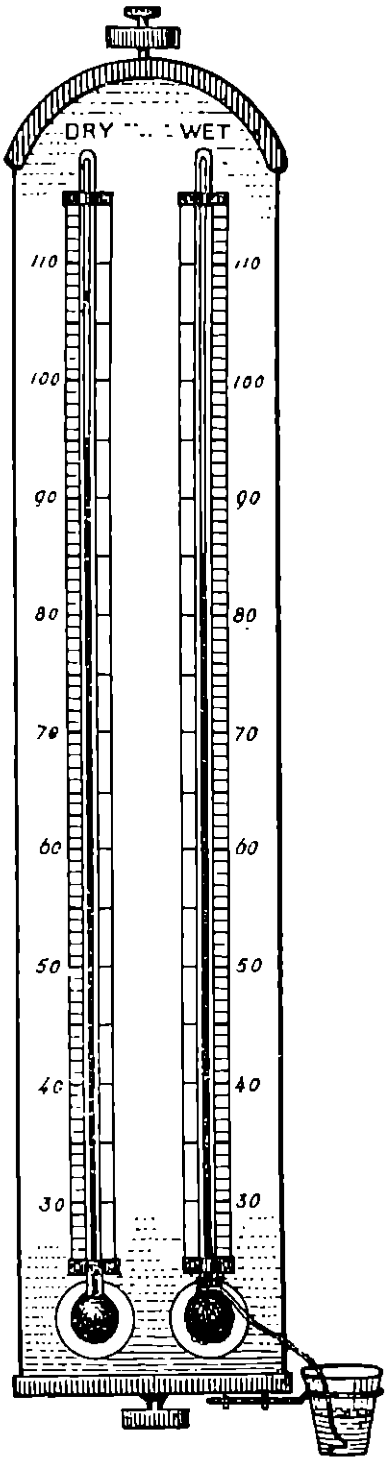

FIG. 18. Wet and dry bulb thermometer.

The dry bulb temperature is that of the air: the wet bulb temperature is *not* the dew point, but if the dry and wet bulb readings are known, the dew point can be calculated: the calculations are elaborate, but have been drawn up in tables, known as Glaisher's tables, and by consultation of these tables the dew point is at once found. The great advantage of the indirect over the direct methods, provided that the necessary tables are at hand, is that in the former the thermometer readings are steady and so can be determined with absolute accuracy.

By means of the wet and dry bulb thermometer and Glaisher's tables we are also able to determine the amount of water vapour, and, most important of all, the **degree of humidity** of the atmosphere.

Let us consider what this means. Hot air, as we know, can take up far more water vapour than cold air, and thus far more water vapour is required to saturate it. On a hot day, therefore, the air may contain more water vapour than on a cold, and yet be further away from saturation. In other words the hot air can still take up more water vapour than the cold, and so will feel dryer and have a more active drying effect, *although it*

actually contains more water vapour. Consequently, it is not so important to know how much water vapour is in the air, as to know how near the air is to saturation. The *degree of humidity* of the air is the proportion which the amount of water vapour actually in the air bears to the amount required to saturate it. If the air is saturated, the degree of humidity is 100 per cent. : if it is half saturated, the degree of humidity is 50 per cent. About 70–5 per cent. is the commonest condition of the air.

The following figures, taken from Glaisher's tables, illustrate this rather difficult point. They need not, of course, be remembered in detail. It will be seen that in each case the amount of water vapour per cubic foot of air is almost the same, but the relative humidity is much less in the warmer air.

Dry bulb.	*Wet bulb.*	*Dew point.*	*Water vapour per cubic foot of air.*	*Degree of humidity.*
80° F.	60°	46·3°	3·4 gr.	31 per cent.
70°	56°	45·2°	3·3	41
60°	52°	44·2°	3·3	58
50°	47°	43·8°	3·3	80 ,,

The methods of determining the amount of **sunshine and rainfall** need not be here described : we need only say that sunshine is measured by time, and rainfall by depth.

The amount of **sunshine** has an immense effect on climate. Sunshine increases both the warmth and the apparent dryness of the atmosphere, for though evaporation takes place readily the warm air is able to hold the vapour more easily. Further, it is an undoubted fact that sunshine tends to destroy many of the germs of disease, and the cheering effect of a bright sun is beneficial both to healthy people and invalids. The dangers of exposure to the excessive radiations of a tropical sun have already been mentioned.

Rainfall is the result of the condensation of water vapour in the upper levels of the atmosphere ; the condensed vapour falls in the shape of rain (or, if frozen,

hail or snow). The water vapour and, therefore, the rainfall, is all derived from the evaporation of the water in the sea or on the surface of the land : evaporation is much more rapid on a sunny than a cloudy day, partly because the warmed air beside the ground can itself take up more vapour, and partly because the convection currents are constantly bringing fresh quantities of air to the ground : evaporation is also enormously increased on a *windy* day for the same reason, i.e. fresh air is constantly being brought to the surface. This also explains why we feel colder on a windy than a still day, for the wind causes evaporation from our skins (see also p. 168) : evaporation uses up a great deal of heat, and our skins are therefore cooled down, and it is from the skin that we derive our sensations of heat and cold.

Since evaporation uses up a lot of heat the earth's surface must be cooled by the evaporation which is always going on : this heat is, however, largely returned to the earth when the rain falls again. Rainfall will be discussed further when we are dealing with the subject of water. A due amount of rainfall is necessary and beneficial both to the animal and vegetable world : too much rain, however, is depressing to man and ruinous to crops.

We may now consider the nature of the local conditions, apart from latitude, which tend to produce different climates in different parts of the world. A *healthy climate* may be described as follows. The temperature should be moderate, and the variations should not be very great—neither very hot days followed by very cold nights, nor very hot summers followed by very cold winters. There should be plenty of sunshine, and the degree of humidity should not be great (in other words, the air should feel dry). The rainfall should be moderate, and fairly evenly distributed throughout the year, so that there are not long periods of drought followed by periods of excessive rainfall. Finally, the country should not be exposed to either very violent or very cold winds. While such a

climate as that described above may justly be considered as highly desirable, it must be remembered that we are creatures of habit, and custom will fully inure us to most climates. We judge of a climate by its effects on a whole people, and not by isolated instances. No book on hygiene, especially for English-speaking people, is intended to support the idea that a good climate is a necessity to life; English-speaking people live and thrive in most parts of the civilized and uncivilized world. This does not, however, alter the fact that some climates are better than others.

The terms 'bracing' and 'relaxing' are somewhat difficult to define; it is probable that the bracing nature of a climate depends largely on its dryness. The east coast of Norfolk and the south coast of Devon and Cornwall are perhaps the best examples in our island of bracing and relaxing climates, and the prevailing winds of the east coast, though colder, are far less moisture-laden than those in the south-west corner. Both climates are admirable in their way; the former is the more suitable where warmth is not the first consideration, as in the case where a man wants to get thoroughly 'fit' during a holiday between long spells of work: the latter for people recovering from actual illness, or for those who are not strong and have to live quiet lives. Here, again, this must not be taken to mean that an energetic life is out of place in South Devon, but merely that the climate does not predispose to it so strongly as on the east coast.

The sea. The most noticeable feature about the climate of countries which are influenced by the sea is that the temperature is more uniform than in continental countries. The English seasons differ from each other far less than those in places of the same latitude in Russia. The reason for this lies in the fact that the sea takes much longer to heat than does the land, and, vice versa, that it takes much longer to lose its heat. This is due to two main causes.

(1) A larger amount of heat is required to raise the temperature of a given mass of water than of an equal mass of land.

(2) The motion and currents of the sea are constantly bringing fresh quantities of water to the surface. Hence in summer the sea is cooler than the land and in winter it is warmer: in summer, therefore, winds from the sea tend to cool the land, and in winter to warm it. Such effects carry for a great distance, but actually on the sea-coast they may be felt on a smaller scale in the phenomena known as *land and sea breezes.* On a hot sunny day the land heats quickly: the hot air rises, and cool breezes from the sea flow in to take its place; thus during the day there is a sea breeze. After sunset the land cools rapidly and the reverse occurs: during the night, therefore, there is a land breeze.

Ocean currents also have a notable effect on the temperature of lands lying in their course: here, again, we may get an example by comparing our own country with another of a similar latitude. The Gulf Stream, rising from the heated waters of the Gulf of Mexico, flows across the Atlantic and washes our western and southern shores, and materially raises our average temperature: the coast of Labrador, on the other hand, is washed by a cold current from the Arctic seas, and the average temperature is vastly lower.

The sea also affects the *rainfall* of a country, since the winds which blow from it are moisture-laden; the greater the expanse of water they have crossed, the larger the amount of water they carry; the south-west winds which have blown over the Atlantic lead to far more rain over the British Isles than do the east winds from the North Sea.

The question of rainfall is also largely affected by **mountain ranges.** If a moisture-laden wind strikes a mountain range, the air is forced upward into the cold levels above, and the water vapour condensed into clouds which fall as rain. Thus the windward side of a mountain

range robs a wind of much of its moisture, and the leeward side obtains but little. In considering the effect of mountain ranges upon climate, one has to consider the direction and the nature of the prevailing winds. Thus in the British Isles the prevalent winds are westerly and south-westerly, and the westward slopes of a range such as the Pennine range, which runs north and south, are far wetter than the eastward.

The Himalayas give, on a large scale, one of the best instances of the effect of mountain ranges upon climate. North of the Himalayas lies Central Asia, and south lie some of the northern provinces of India, such as Assam. Central Asia is a high plateau fully exposed to the northerly winds and is cold; the Himalayas, however, shelter Assam from these winds and its temperature is much higher. On the other hand, the moisture-laden south-west winds (which we already know as the south-west monsoons) sweeping over the great plains of India, still retain much of their moisture when they reach the Himalayas, and this moisture is deposited upon the southern slopes, so that Assam is moist and fertile while Thibet is dry and barren. The mountains have, therefore, a double effect sheltering from cold and precipitating rain.

Many other examples of similar effects may be found, and the reader should try to work some out. It must be remembered that, at times, bitter local winds may blow from the mountain slopes to the plains below.

Proximity to mountain ranges must not be confused with **altitude.** The chief effects of altitude we already know, namely increased cold and a rarefied atmosphere, so that acclimatization and training are necessary, if the height is great, before full exercise can be taken. The air at a reasonable altitude is keen and bracing, and extremely beneficial in many illnesses for people with weak hearts, however, a great altitude is dangerous. Rainfall is great if one is exposed to moist winds on the other hand, we must remember that on the right exposure

there may be far more sunshine than in the sheltered valleys below.

The presence of **forests** tends to make a climate moist and warm, and this is due to two causes: in the first place, forests, like mountains, though to a smaller extent, act as condensers and lead to precipitation of rain : in the second place, evaporation from the ground is greatly hindered, for (1) the sun's rays do not get free access to the ground, (2) winds cannot sweep so freely over the ground, and therefore the air is more imprisoned and more quickly saturated.

Vegetation such as crops and grass increases evaporation, for the roots suck up moisture from the ground and the shoots supply it to the air. The air is, therefore, moister and the ground cooler and dryer than in fallow land under similar atmospheric conditions.

CHAPTER V

WATER

PURE water is formed by the combination of two volumes of hydrogen with one of oxygen, and is, therefore, an example of the fact that substances may combine to form something totally unlike themselves, for both hydrogen and oxygen are gases.

Water is used in ordinary life for (i) **drinking**, (ii) **washing and cleaning**, (iii) **cooking**, and (iv) **trade purposes.** For all these purposes certain qualities, differing to some extent in the different cases, are desirable ; that is to say, washing, cooking, &c., can be performed better with some waters than with others. In drinking-water, however, the right qualities are not merely desirable, but vitally important, for many kinds of disease may be caused by impure drinking-water, and, further, it is plain that when many people use the same water, these diseases may be very widespread. The most pleasant-tasting water may contain disease germs, so that people may contract disease without anything to warn them that they are running risks ; the dangers of water are, therefore, very insidious, and it is very important that water supplies should be properly controlled and managed, so that people may drink in safety and without fear. Here in England we drink our water out of the taps in our houses and do not give a thought to the fact that water sometimes contains disease germs, but in many less civilized countries no educated man dare drink water without first taking steps to render it pure, for he knows that the risks are too great. In many country places in England similar precautions ought to be taken where water is obtained from wells and streams, though the risk is not so great : in towns, however, we simply take it for granted that the authorities have done all that is necessary to our water before it is allowed to flow to our houses at all.

Ordinary observation will help us a great deal in judging of the purity of water: the water should be *clear, sparkling, colourless,* and *free from odour,* and, on standing, there should be *no deposit.* Any water that does not come up to this standard should not be drunk. Even if it does, however, it cannot be said certainly to be pure until it has been subjected to the proper scientific tests; ordinary observation is not sufficient in itself.

Impurities in water. The dangers of water depend on the amount and nature of the impurities which it contains; these may be classed in the two groups of (*a*) *dissolved impurities* and (*b*) *suspended impurities.*

(*a*) *Dissolved impurities.* If a lump of sugar is dropped into a glass of water, it will gradually disappear; the water will, however, taste sweet, which shows that the sugar is *still there*—that, though it has disappeared, it has not been destroyed. If the water is boiled away the sugar will be left behind in a solid form again. The water is said to have *dissolved* the sugar.

In a similar way water dissolves many of the **salts** found in the soils or rocks, through or over which it flows. Now it was stated in the last chapter that the blood plasma contains some salts in solution; we shall find, too, that salts form an important part of our food, and it is necessary now to get a rather clearer understanding of what a salt is. A full and accurate definition of a salt cannot be understood without a proper knowledge of chemistry; it will be sufficient here to define a salt as a *combination of a metal with an acid.* The following is a list of the metals which concern us most, on the one hand, and of acids on the other.

Metals	**Acids**
Sodium.	*Carbonic acid.*
Potassium.	*Hydrochloric acid.*
Calcium.	*Sulphuric acid.*
Magnesium.	*Phosphoric acid.*
Iron.	
Lead.	

Any of these metals can combine with any of the acids to form salts, and the names given to the salts show clearly of what they are composed. For instance

Sodium carbonate (washing soda), from sodium and carbonic acid.

Sodium chloride (common salt), from sodium and hydrochloric acid.

Calcium carbonate (chalk), from calcium and carbonic acid.

Magnesium sulphate (Epsom salts), from magnesium and sulphuric acid.

One more substance, namely *sulphur*, should also be mentioned, for it is found in water in direct combination with other elements ; for instance, hydrogen and sulphur will combine with each other to form *hydrogen sulphide.* Sulphuric acid contains sulphur, so that magnesium sulphate and all other sulphates must also contain it, but a *sulphide* will contain proportionately much more.

The various metallic salts are found distributed through the various soils and rocks of which the earth's crust is formed, and salts are present in varying amounts in all natural waters except rain water—that is to say, in all water which has passed through or over the ground.

Different waters contain very different amounts of salts for two reasons : (i) because different soils and rocks contain quite different salts, and (ii) because some salts are much more easily dissolved than others.

The various waters which are drunk at ' spas ', such as Bath or Harrogate in England, or Carlsbad or Aix abroad, are examples of waters with a very large amount of dissolved impurities ; sulphur and iron are often contained in such waters as well as the more ordinary salts.

These waters are quite unsuitable for ordinary drinking purposes, but are useful for various invalids' complaints. Sea water is another example of water containing a great deal of dissolved salts ; rivers are constantly bringing in fresh supplies of these, and the water from the surface

of the sea is constantly evaporating and leaving the dissolved impurities behind it, with the result that the percentage of these is very gradually increasing. As every one knows, sea water is quite unfit to drink.

The Dead Sea, which is a large lake with no outlet, is far more concentrated still, and crystalline masses of salt are deposited round its shores.

We may say, with sufficient accuracy, that a small quantity of dissolved mineral matter improves the qualities of drinking-water, but that any large amount makes it quite unfit to drink. The following table bears this out and also shows how very great the variation is.

Parts by weight of dissolved salts in 1,000 parts of water:

Rain water	0·03	Insipid.
River water	0·1	Good-tasting water.
Spring water	0·3	
Deep well water	0·4	
Spa water (Bath)	2·37	Unsuitable for ordinary use.
Sea water	35	Unfit to drink.
Dead Sea	228	

We must, however, bear in mind that it is not *only* the amount, but also the nature, of the dissolved salts that affects the qualities of water. This question will be considered more fully when we discuss the various natural waters in detail.

Lead, which was mentioned in the table on p. 81, is hardly ever found in *natural* waters, but is sometimes dissolved by water in its passage through lead pipes. Since lead is acutely poisonous, it is of great importance to know what kinds of water may safely be run through lead pipes, for these pipes are still more common than any others. This question also will be considered later.

Besides dissolving salts, water also dissolves a certain amount of **gases** contained in the atmosphere through which it falls, and the ground through which it passes. The gases in pure air are quite harmless: water which does not contain air in solution is, in fact, dull and

insipid. Some of the ground gases, and those in the air in the neighbourhood of towns and, especially, factories, may be harmful and unpleasant. An interesting fact about gases in solution is that they may enable water to dissolve some solid materials more easily: we shall find that this is specially the case with compounds of calcium.

Water may also dissolve some **organic matter**, derived from the soil. This *may* be harmless, but the presence of organic matter is always very suspicious, and water which contains dissolved organic matter in more than a very small quantity is not considered fit to drink.

(*b*) *Suspended impurities*, as in air, may be inorganic or organic. Inorganic matter is fairly easy to detect because it discolours the water: a mountain stream, after heavy rain, contains a great quantity of suspended inorganic matter such as earth and mud, and is then turbid and non-transparent. Organic matter may be dead or alive; the larger particles are easily seen. The chief danger lies in the presence of *bacteria*, which, as we know, are far too small to be seen. Among the diseases which are known to be caused by bacteria in water may be mentioned cholera, typhoid fever, and dysentery. The dangers of drinking water without proper care, and so absorbing suspended bacteria, are, perhaps, best shown in the history of military campaigns. In nearly all of these, if prolonged, the deaths from disease have been far more numerous than the deaths from wounds, and the majority of these diseases have been found to be due partly to insanitary conditions and partly to the careless drinking of wayside water. It is now a punishable offence for a soldier on active service to drink water which has not been properly purified. In the Russo-Japanese war, the Japanese discipline in the matter of water was very strict indeed, and the number of deaths from disease was very remarkably small.

Let us now consider the **natural sources of water**, and the impurities which they may be likely to contain. Remember always that it is the presence of *organic*

matter, whether dissolved or suspended, but chiefly suspended, that particularly affects the safety of drinking-water. Inorganic matter, unless present in large quantities, will merely affect the taste.

The air, as we know, is constantly taking up water vapour by evaporation from the surface of the earth and sea: the water vapour condenses to form clouds, and these break up, so that the water is returned to the earth or sea as rain: from the rainfall all our sources of water are ultimately derived. Of the rain which falls on land, (i) part is again evaporated, (ii) part flows along the surface to form streams and rivers which flow into the sea or into lakes, and (iii) part sinks into the ground, from which it may emerge in the form of springs, or be obtained by sinking wells.

Rain water collected in a clean vessel in the open country is the purest natural water obtainable: it has only dissolved some of the atmospheric gases, and picked up a little of the suspended matter in the atmosphere. It is a little insipid to the taste, since there are no mineral salts, but, for the same reason, is an excellent washing water. Rain water is often stored in butts, which collect the water draining over the roofs of houses and sheds: in this condition it is no longer pure, especially in towns, for it will have collected dust, soot, and organic impurities.

Stream, river, and lake water, or, as it is called, *surface water*, varies very greatly in its properties. The amount and nature of both dissolved and suspended matter depends on the nature of the soil over which the water travels. The water in rivers which flow over rocky uncultivated country is far purer (i.e. safer) than that in cultivated country, though it may contain more mineral matter. In cultivated country river water is apt to be very unsafe. In the first place the water picks up great quantities of suspended matter from the soft banks and bed of the river: in the second place impurities derived from manure, drainage, and the presence of animals on

the banks contaminate the water; the impurities from both sources are greatly increased in times of flood. When passing towns the quantity of drainage is greatly increased, and, in addition, factories may pass out polluted water into the river. The fact that river water is in motion tends to purify it, for it brings fresh water into contact with the oxygen of the air: fishes and plant life also have a purifying effect, and many bacteria, though they are impurities themselves, tend to render water pure. All these, however, are quite unable to cope with serious pollutions, and the state of many English rivers has been very bad: it is now better, since drainage is generally purified before it is allowed to flow into a river, but, nevertheless, river water in cultivated or populous country is not safe to drink. Stream water, above cultivation, especially in rocky country, is usually quite wholesome. For washing purposes the quality of the water depends on the quality of the soil it has passed through.

Lakes, if there is a good outflow, contain but little more dissolved matter than the rivers which flow into them; the slight increase is due to evaporation, and the condition of a lake such as the Dead Sea, where there is no outflow, has already been considered. Suspended matter, on the other hand, is less in amount than that in the inflowing rivers, for the matter gradually settles down to the bottom; fishes and plants further improve the condition of the water, and the lake water, if the outflow is good, will generally be purer than the river water.

Springs and wells contain water which has sunk into the ground. A well is not strictly a natural source of water, for wells have to be made, but it is natural in the sense that a man can go and get water from it in a natural condition.

The earth is not all of the same composition, but is made of many kinds of soil and rock, the nature and arrangements of which vary very much at different places. This is best seen, perhaps, in the cliffs on the sea coast,

which may be of chalk, as at Dover, or granite, as at Land's End, or of many other varieties. Some of these formations allow water to sink into them and pass through them, and these are known as *permeable* formations; others, which are called *impervious*, do not allow the passage of water, or only allow it to a very limited extent. Water falling on ground where impervious soils come to the surface, or water falling on steep slopes where it can run off quickly, will hardly sink into the ground at all: water falling on to other soils, especially in level country, will sink in, and will continue to sink, until it reaches some impervious formation. Of the common formations, sand and gravel are far the most permeable, then chalk (which is a form of limestone), then the other limestones which are only slightly permeable, and finally clay and the hard rocks, such as granite, which are practically impervious.

The amount of water in the soil will naturally vary greatly with the rainfall; it will also vary with the seasons, for there is far more evaporation in summer than in winter, and consequently less water in the soil. The ground is much wetter in winter than summer, not because the rainfall is greater, but because the evaporation is less.

The various formations of soil or rock lie in layers or *strata*, and it should be clear that there is very commonly a large quantity of water in the soil immediately above the *first impervious layer*. One might, at first, think of this water as forming vast underground lakes, but when we remember that the various layers are not flat and level throughout their area, but have, as a rule, a slope one way or the other, it is clear that it is better to think of it as forming vast underground *rivers*. The important thing to remember is that, if given time, most of the water will be able to flow away, the rate at which it flows varying with the slope of the impervious layer beneath it, and the ease with which the water can pass through the soil in which it is contained. Suppose, however, a place where the upper surface of the first

impervious layer is cup-shaped. In this case the water will be more comparable to a lake. This water can only escape when its level is above the brim of the cup.

Now if this water, which is known as *ground water* or *subsoil water*, is able to flow away, it is clear that it must come out of the surface of the earth at some point or other. The point at which the water escapes is the point at which the permeable and impervious strata reach the surface of the earth together; here, at the junction of the two strata the water will appear in the form of a **spring.** The diagram should make the nature of a spring clear; it will be seen that a spring is either the escape of an underground river or the overflow of an underground lake (see p. 91).

This spring water will have passed through a great deal of soil, and will have been thoroughly filtered; spring water, therefore, unless exposed to pollutions near its source, is clear, wholesome water, and free from suspended matter. It will contain mineral matter dissolved from the soil through which it has passed, and may be bad water for washing purposes.

If a hole be bored in the earth sufficiently deep to reach the level of the water in the permeable soil, water is bound to appear at the bottom; such a hole is known as a well. If the bottom of the well is in the same stratum as the mouth, the well is called *shallow*;[1] if, however, the top stratum does not contain sufficient water and the well has to be sunk through an impervious stratum below, so as to tap the water in a permeable stratum yet further down, the well is called *deep*. These words are a little misleading, for a shallow well may be deeper than a deep. Suppose, for instance, two wells, one sunk through 100 feet of chalk and the other through 30 feet of gravel, 15 feet of clay, and 45 feet of chalk (or 90 feet in all); the former is a shallow well and the latter is a deep well. The special meanings of the terms deep

[1] The term *surface well* is, perhaps, better than *shallow well*, as there is no likelihood of its being misleading.

and shallow, as applied to wells, must, therefore, be remembered.

A well drains a great amount of land, so that several wells sunk near each other do not provide much more water than one well.

Wells should be lined with brick and clay, so as to be watertight, and allow water to enter at the bottom only ; the lining should be carried up 2 or 3 feet above the

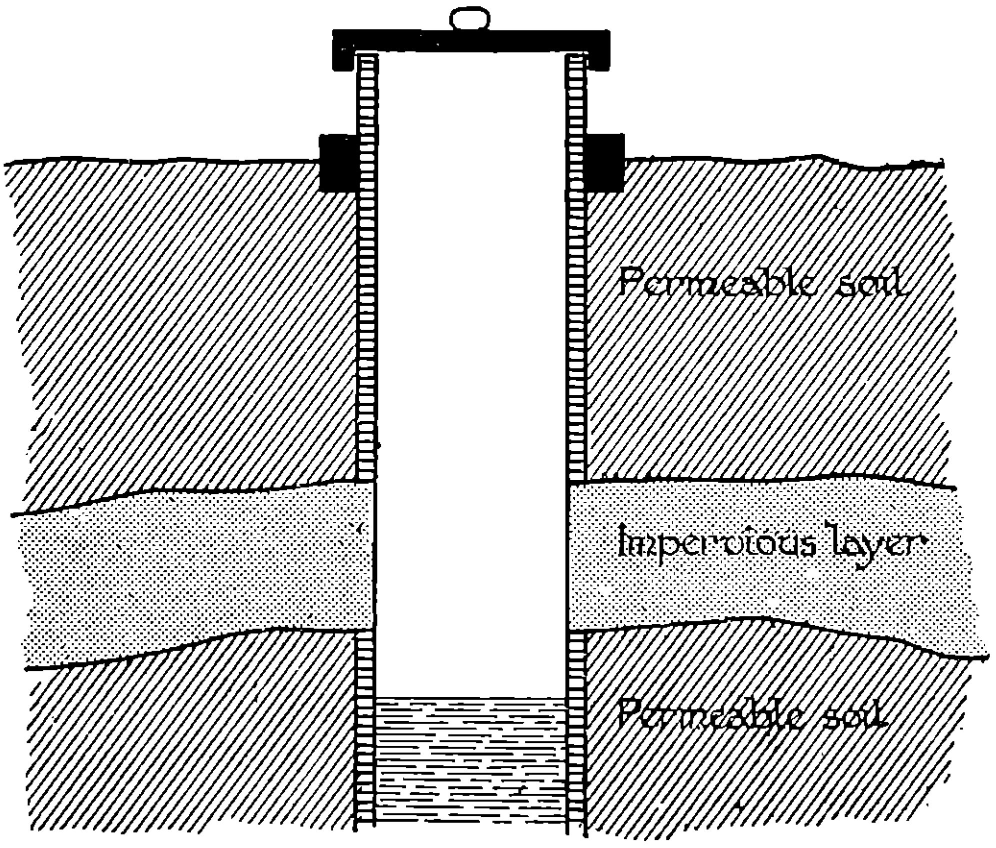

FIG. 19. Diagram of construction of well.

surface of the ground, and the well should be provided with a cover. When constructed in this way no water can drain in through the sides, nor can surface water flow over the edge ; this is of the utmost importance, for in either case the water might, and probably would, carry impurities with it, for the mere fact that a well is needed at all generally means the presence in the neighbourhood of houses, sheds, drainage, cattle, &c., and, consequently, of contaminated ground.

A well must, therefore, be very carefully constructed,

and, as a general rule, the deeper (in actual depth) a well the purer will be the water, for the greater depth ensures greater filtering of the water in its passage through the soil : shallow wells, then, are not so likely to contain pure water as deep wells. This rule is by no means invariable, however, for a deep well may tap contaminated soil, and a shallow well may tap perfectly clean soil. Depth, therefore, is not the only consideration which affects the purity of well water, though, *other things being equal, deep well water is the purer water, owing to the greater extent of the filtering action of the soil.*

It sometimes happens, in places where an impervious layer comes near to the earth's surface, that the ground is actually *below* the level of the water in the permeable layer below; if in such a place a well be sunk the water will flow out of the mouth without any necessity for pumping or drawing. A well of this kind is known as an *artesian* well, and is usually very deep : some artesian wells supply an enormous amount of water, as for instance the Grenelle artesian well sunk near Paris, which took seven years to sink, was 1,800 feet deep, and yielded for some time 700,000 gallons of water per day.

Deep well water usually contains even more mineral matter than spring water, for it remains in the soil for a longer time : it must be clearly understood, however, that no exact measures of the nature of spring, well, or river water can be given, for they vary very greatly : we can only describe their *average* compositions.

Water supply and purification. People who live in towns obtain their water by turning on a tap, and trust, for its purity, to the company or public body which supplies the water the water is purified before it is supplied to the town, and we must discuss, later, the way in which water is obtained and purified on a large scale. In thinly populated districts, however, water is frequently obtained from natural sources : if it is known to be pure, no further purification, obviously, is needed : it should, however, be tested from time to time to see that there

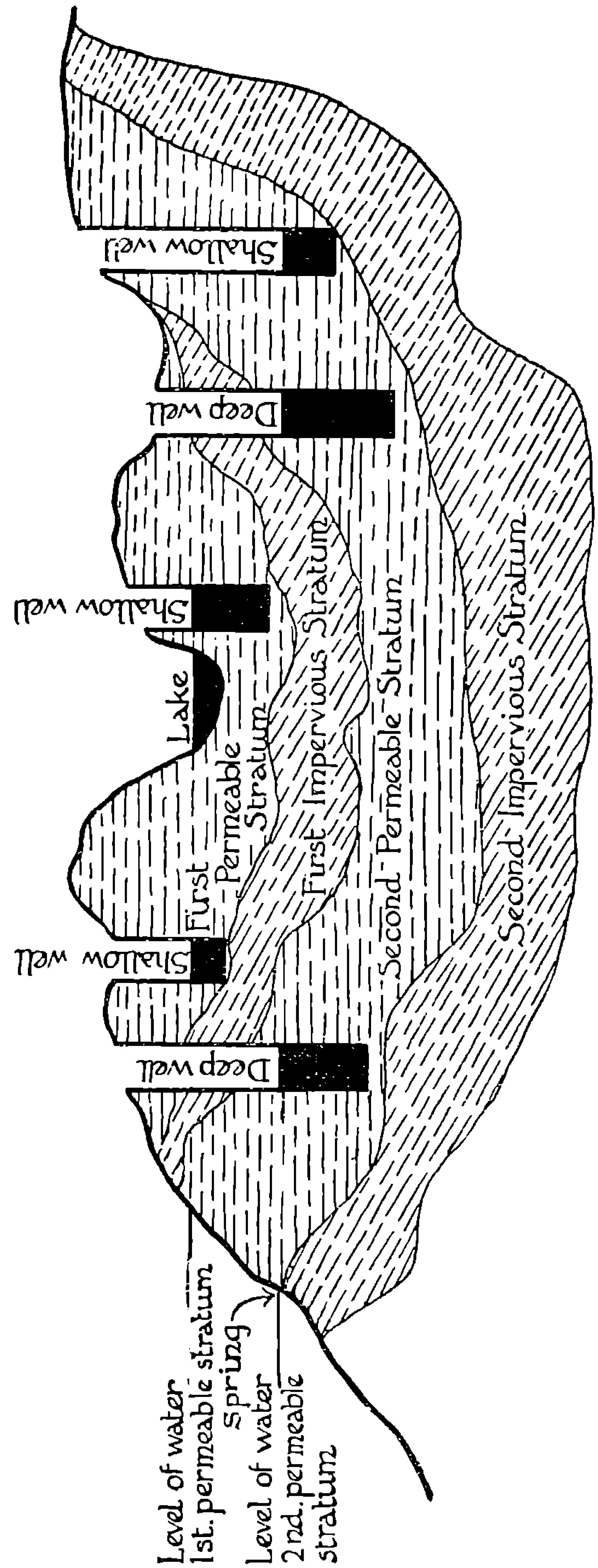

FIG. 20. Diagram of deep and shallow wells and spring.

is no unsuspected source of contamination. If water is not pure, or if nothing is known about it, those who use it should always purify it before drinking it. The following means are employed :

(i) *Distillation*, which renders water absolutely pure.
(ii) *Boiling*, which destroys all bacteria.
(iii) *Filtration*, which removes suspended matter.

For washing purposes *chemical methods*, and also boiling, are used, but chemical means are not the best for drinking-water.

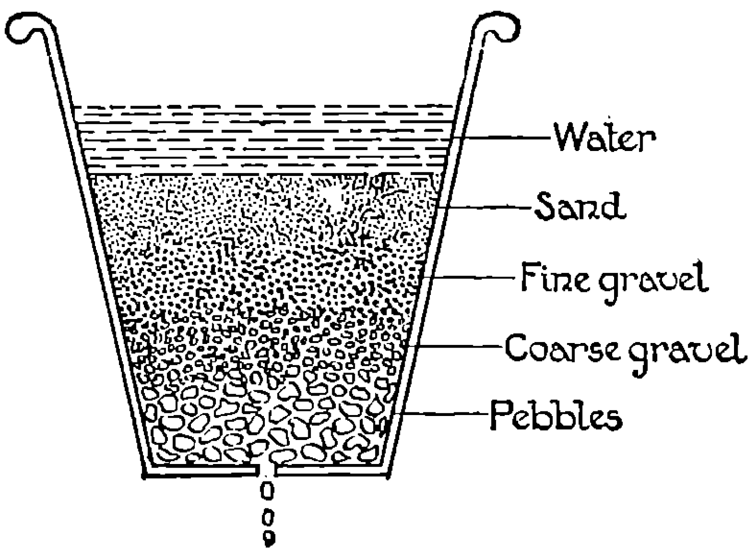

FIG. 21. Diagram of simple sand filter.

In distillation the water is boiled and the steam passed through a long coiled tube which is immersed in water : the far end opens into a carefully guarded vessel, and the condensed steam drops into this as perfectly pure water. The process is too complicated for ordinary use, but distilled water is used greatly in chemical and other laboratories. Distilled water is insipid to drink, but is improved by allowing it to drop through the air, through a sieve or rose, so that it becomes aerated. By distillation even sea water may be converted into pure water.

Ten minutes' boiling is generally sufficient to kill all bacteria, and will make any clear water perfectly *safe* to drink : it does not, however, remove suspended matter, and, with turbid water, filtering is also necessary.

Boiled water, like distilled water, is rather insipid and requires aeration. Boiling causes some of the mineral salts to be deposited in a solid form ; distillation has this effect with *all* salts.

In filtration water is passed through material, the pores of which are too small to allow suspended matter to pass : this is, therefore, caught on the filtering material, and clear water runs through. To arrest bacteria the pores of the filter must, obviously, be exceedingly small.

A fairly efficient filter may be made in an ordinary flower-pot by placing in the pot a few pebbles, and covering these with successive layers of coarse gravel, fine gravel and sand. The *sand* is the true filtering material and the gravel forms a good bed on which the sand can rest, while the air between the gravel stones aerates the dripping water : all the materials must be thoroughly clean, and must be frequently renewed. On a filter of this kind the majority of the germs are caught, though a few may pass through : the filter costs nothing to make, and is sometimes known as the 'poor man's filter'. We shall see that this principle is used on a larger scale for filtering large quantities of water.

Charcoal is a common filtering medium, and is excellent, provided it be *frequently cleaned and occasionally renewed.* Otherwise charcoal becomes a regular danger-trap, for the bacteria gradually sink deeper and deeper into it, and eventually the water washes them through in great quantities. The charcoal may be in a solid block, or in a powdered form resting on asbestos. The cleaning is performed by scrubbing (in the case of a solid block), followed by the prolonged passage of weak acid, and finally copious quantities of water. A special virtue of charcoal is that it seems to have the power of removing dissolved lead.

Berkefeld's and *Chamberland's* filters are extremely effective: the former is made of a special earth and the latter of *unglazed porcelain.* They are generally made in the form of cylinders, or, as they are called, *candles,* which

can be fitted on to a tap, so that the filtering takes place *under pressure*: otherwise, filtration is extremely slow. The diagram of the whole apparatus shows that the water is passed from the outside to the inside of the candle: if the flow gets slow it is a sign that the filter requires cleaning, because it is getting clogged: the filter is cleaned by thorough scrubbing with a hard nail-brush, and it is then subjected to heat, so that any germs remaining in it are killed: the greatest care must be taken to see that it is not cracked, for, if so, all its efficiency is lost. If the water to be filtered is thick and muddy the filter will soon get clogged: it is better, therefore, to pass turbid water through some coarse filter first.

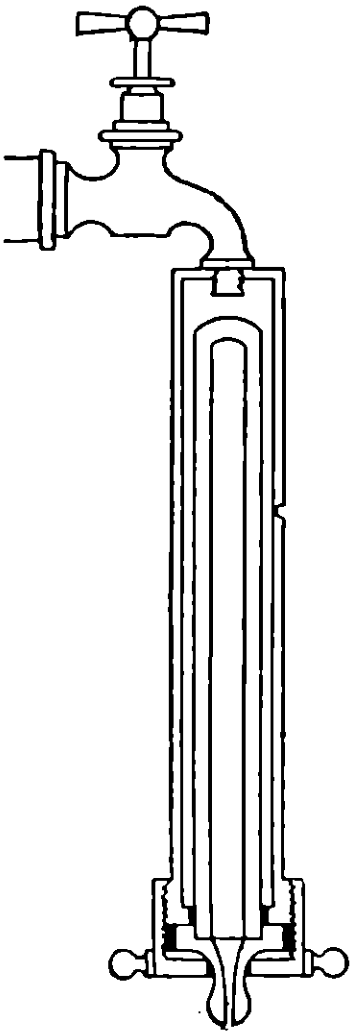

FIG. 22. Chamberland's filter on tap.

These filters are extremely efficient, and will remove practically every germ: from what we have said it is plain that filtration is quite sufficient to purify water for drinking purposes, if the filter is of a good pattern and in good order: with inefficient or makeshift filters it is wise to boil the water first.

Water supply to towns. On a large scale pure water is supplied by public bodies or companies, whose duty it is to see that it is pure: it is submitted to proper tests before reaching the consumer. Water which is already reasonably pure is, naturally, easier to make completely safe than very impure water, and the first essential is to obtain a *source* of good water. As a result, many towns obtain their water from a long way off: Liverpool, for instance, is supplied by the river Vyrnwy in North Wales, sixty-eight miles away. The source in such a case must be at a sufficient altitude to allow water to flow steadily to the town in question. There must also be a *constant*

and sufficient supply, so that the effects of the longest droughts must be carefully considered. Sometimes a natural lake is tapped, but more commonly the valley of a stream is dammed, so as to form an artificial lake, or *reservoir*. The law generally provides that, in such a case, arrangements must be made to allow a proper supply of water to flow down the bed of the river beyond ; otherwise hardship would be inflicted on those who lived on the banks below.

The water is usually conducted from the reservoir in large iron pipes, buried a few feet below the ground so as to be safe from frost : these pipes are so arranged that they can be readily cleaned at intervals. The water then passes into a second reservoir [1] nearer to the town, and from here into *filter tanks*, which are very frequently constructed upon the principle of the 'poor man's filter'. The tanks are made of brick or concrete, and are about 8 feet deep, and the beds are composed of about 3 feet of stones and gravel, over which lie 2 feet of sand. The larger stones are at the bottom, coarse gravel next to these, and fine gravel under the sand. The water is allowed to reach a level of 2–3 feet above the sand. Below the stones the filtered water drains away and passes to large tanks known as *clear water tanks*. From these it is distributed by *mains* to the various thoroughfares, and from the mains *service pipes* are led off to the houses. The mains should be well away from sewers and gas pipes under the streets, and at intervals there should be *hydrants*, by which water can be obtained for use at fires, or for street-cleaning purposes. The service pipes are generally made of lead, so that the many bends and joints are easily made. If the particular water supplied has any tendency to dissolve lead, ordinary lead pipes

[1] Whatever the source of the water, it must be raised to an altitude above the town before distribution. If the water is obtained from a river at the town level it is generally pumped up to a reservoir on some eminence near by, or, failing this, into *water towers*. Similarly, if the main part of a town is low lying, but has outlying high parts, water towers with large tanks may be erected for this local supply.

must not be used: there are many substitutes, among which may be mentioned iron, which is more difficult to bend and which may give trouble by rusting, and a compound pipe made of lead lined with tin.

The sand in the filter tanks gets clogged after a time, and the water begins to pass too slowly. If the sand is now examined it is found that there is a very fine slime on the surface: this, to a certain extent, penetrates the deeper layers of sand and is found greatly to increase the efficiency of the filtering; the sand is, therefore, not completely removed, but only about half an inch is scraped off the top, and a similar amount of fresh sand put in its place.

Water is supplied to towns on two systems, the *constant* and the *intermittent*. In the former water may be obtained from the taps any time of the day or night: in the latter the water supply is cut off at a fixed time in the evening and turned on at a fixed time in the morning. The single advantage of the second system is that less water is used, and so it is less wasteful: the disadvantages are many and great, and the constant system is far preferable. (i) It is much more convenient, (ii) it is much safer in the event of fire, for water can always be obtained from the mains, and (iii) it is more hygienic, for an intermittent supply means the use of storing cisterns in every house, and these are always a possible source of danger unless constant care be taken.

The water supply of towns in Great Britain is generally sufficiently large to provide about 25 gallons per day per head: i.e. about 2,500,000 gallons a day in a town of 100,000 inhabitants. About three-fifths of these are used for personal and domestic purposes, and the remainder by municipal bodies and for trade purposes. The amounts used, however, vary very much from time to time.

Hard and soft water. Hard water is water with which soap will not readily form a lather: the hardness is due to certain dissolved salts, of which the most important are

compounds of calcium and magnesium: the presence of iron also makes water hard. By far the commonest of these salts is one known as *calcium bicarbonate*: this is not found to any extent in the earth formations, but another salt, *calcium carbonate* is very common, for chalk and marble rocks are nearly pure calcium carbonate, and other limestone formations contain a very large quantity. The names of these salts signify that they are compounds of calcium and carbonic acid: the prefix 'bi' in bicarbonate signifies the presence of a double quantity of carbonic acid. Now pure water will not dissolve calcium carbonate: the water which reaches the chalk formations, however, contains carbonic acid derived from the atmosphere, and from the air contained in the ground near the surface. This carbonic acid combines with the calcium carbonate, and so forms calcium bicarbonate, which is *soluble*: water, therefore, which has flowed through chalk or limestone will contain calcium bicarbonate in solution, and will be hard.

If soap be used with this water a curdy substance, which is a combination of a fatty acid contained in soap with calcium, will be produced in place of a lather. When all the calcium has been used up a lather can be produced. In other words the water has been made *soft,* but the process has wasted time and labour and soap.

It is therefore better, if possible, to make this water soft before using it for washing, and this can be done by *boiling.* Water which can be softened by boiling is said to possess *temporary hardness.* With the water we have been describing this effect is due to the fact that, in boiling, the extra carbonic acid is driven off as gas, and the bicarbonate is therefore converted into carbonate since this is insoluble it falls to the bottom of the vessel, and forms the 'fur' so commonly seen in kettles, saucepans, &c. Boiling also gets rid of magnesium bicarbonate in a similar way, and of a great part of any iron which is present.

There are, however, other salts of calcium and magne-

sium, namely, calcium sulphate (gypsum) and magnesium sulphate (Epsom salts), which cannot be got rid of by boiling: water which contains these is called *permanently hard.* As we have already seen, some iron also remains after boiling to cause permanent hardness.

Temporary hardness can also be removed by adding *quicklime,* which causes a similar deposition of carbonates: this method is known as *Clark's process,* and is used to soften water on a large scale, one ounce of quicklime being used for every hundred gallons of water. Washing soda has a similar softening effect, and is much used in the household.

It is plain that water derived from rivers, springs, or deep wells in chalk or other limestone country is sure to be hard: that from rivers will be the least hard, and from wells the most. Most limestone contains magnesia as well as calcium salts, and some contains so much that it is known as magnesian limestone. The *dolomite* mountains in the Tyrol are composed of a form of magnesian limestone.

The disadvantages of hard water may be stated as follows

(i) It is uneconomical, for it causes a waste both of time and soap.

(ii) It leaves a 'fur' behind it when boiled. In kettles and saucepans this trouble may be largely got over by placing a marble in the vessel, for the fur will be deposited on the marble in preference to the sides and bottom of the vessel. The trouble is really more serious in boilers and pipes. Far more heat is necessary to heat the water in the boiler, and the pipes get blocked up explosions may even result.

(iii) A little hardness improves the quality of drinking water, but too much is unhealthy and leads to indigestion and constipation. The presence of magnesia is often said to cause a peculiar swelling of the neck known as 'goître', but this is very doubtful.

(iv) When used for cooking purposes it is found that

a longer time is needed for thorough boiling, and also that the food, especially vegetables, is apt to acquire a mineral taste. Cooking water should be both soft and pure : the necessity for purity is obvious, for the water is in contact with food.

The *advantages* of hard water are (i) that, as already mentioned, moderately hard water is the pleasantest to drink, and (ii) that hard water does not dissolve lead.

Lead in water. The possibility of lead being dissolved in water has been mentioned before this. The amount of lead found varies very much with different waters ; soft water will always dissolve more than hard water, and the worst kind of water is that which comes from moorland or peaty country. With such water there is always some risk, and lead should not be used in the pipes, unless the water is hardened before it is allowed to flow through them.

Two other points have also to be considered.

(1) Water which has stood a long time in the pipes will contain more lead than water which has merely flowed through them.

(2) Hot water dissolves more lead than cold water.

Whatever the nature of the water it is always a wise precaution, where lead pipes are used, to allow the water to run for a minute or two from the cold tap before it is collected for drinking purposes, and never to drink water taken from the hot tap.

CHAPTER VI

FOOD

WHEN combustion takes place in our tissues, the substances which combine with oxygen are used up; they must, therefore, be replaced, and we obtain our fresh supplies of them by taking **food.** Since carbon, hydrogen, and nitrogen are the most important elements in our tissues, it is plain that our food *must* contain these three.

Let us at present, for the sake of simplicity, leave hydrogen out of discussion, for we shall find that the values of different foods depend very largely on the amounts of carbon and nitrogen which they contain.

By far the larger part of the heat produced in the body is due to the combustion of carbon; nitrogen is of comparatively little importance in this respect, but since, when combustion takes place, there is an actual breaking down of the tissues, we are unable to derive heat and energy from the combustion of carbon without some loss of nitrogen also. The internal working of the body is such, however, that the nitrogen is *spared* as much as possible, and as little as possible used up: this fact is very important and will become clearer when the compositions of our food have been studied.

Our foods are all derived from animal and vegetable sources, and are, therefore, complex in their nature, and contain substances similar to those found in our bodies. *The great distinction between the different foods is that some contain nitrogen, and some do not*; they may therefore be divided into the two classes, *nitrogenous* and *non-nitrogenous*. *All* foods contain carbon and hydrogen;[1]

[1] All tissues and all foods contain oxygen also; this is already combined with other elements, and is therefore of no value for purposes of combustion, nor can it combine with fresh oxygen in the body. Oxygen in the food need not, therefore, be considered in this book.

it is plain, then, that a nitrogenous food can support life, for it contains all these necessary substances ; a non-nitrogenous food is not enough by itself owing to the absence of nitrogen.

We shall find, however, that though pure nitrogenous food may be *sufficient*, it is not *satisfactory*, for, in order to obtain enough carbon, we should have to take far more nitrogen than is necessary, and this would throw too much work on our organs of digestion and excretion. *A mixed diet is, therefore, essential to health*, both nitrogenous and non-nitrogenous foods serving their own useful purposes.

The nitrogenous foods are known as **proteins.** They are very complex bodies, and are of many kinds, but are all allied to each other. We have already mentioned more than one protein in the blood and in the tissues, albumin and globulin in both, and fibrin and haemoglobin in the blood only. Albumin and globulin are the commonest proteins of all ; there are many slightly different types of each, which are distinguished from each other by calling them milk-albumin, egg-albumin, serum-globulin, &c., but for our purposes it is sufficient to remember that albumin and globulin are two kinds of protein very commonly found in our foods. The only other proteins we need mention are *casein*, found in milk, *myosin* in meat (or muscle), and *glutin* in bread.

Proteins are found in both animal and vegetable foods, but most of us derive the greater part of our protein from *animal* food.

The non-nitrogenous foods form two great classes, the **carbohydrates** and the **fats.** The chief carbohydrates are the *sugars* and *starches* which are found in abundance, in one form or the other, in most of our vegetable foods. Another carbohydrate which requires mention is *cellulose* : this is not digestible, and, consequently, does not increase the actual value of the foods in which it is contained, but it is so common in vegetable foods that it is of importance : we shall find that, especially in

uncooked vegetables, it is injurious if in large quantity, because it makes the whole food too indigestible: in small quantity it may be useful because it acts as a stimulant to the alimentary canal. We shall speak again later of these properties of cellulose, but may mention here that it forms the walls of the cells of which vegetables and fruits, like animal tissues, are composed.

The fats are found in both animal and vegetable foods, but more particularly in the former. Their *heat value* is greater than that of carbohydrates: in other words, if a certain weight of fat is burnt, it will give out more heat than the same weight of carbohydrate. This applies equally to the slow burning that goes on in the body, and a diet of fat will produce more heat than a diet of carbohydrate. On the other hand fats are rather less digestible than carbohydrates, and, further, the body can make use *more quickly* of carbohydrate than of fat, so that carbohydrate is of more value for the purposes of work and energy. Here we must guard against the mistake of thinking that our foods are burnt up the moment they get into the body: it is the tissues, and the stores of fat and carbohydrate in the body which are burnt up, and the foods provide fresh supplies to take their place. Although we eat a great quantity of carbohydrate foods, there is never very much carbohydrate in the body, for it is quickly stored and quickly used up. On the other hand there is plenty of fat under the skin and amongst the tissues, and this is more slowly used up and more slowly replaced. We are probably not very far wrong, even though we are not strictly accurate, if we say that we derive much of the heat which we have continually to produce to keep up our temperature *from fat*, and that we derive the heat which we are going to turn into work *from carbohydrate*, while the actual breakdown and wear and tear of the tissues proper which is bound to accompany all this combustion of carbon is replenished by *protein*.

The following facts will make this difficult question clearer.

Suppose a man starves for a time, and takes nothing but water. If he is carefully observed during this time it is found that the carbohydrate in his body is very soon used up, and that this is followed by the wasting away of the fat: the protein is slowly used up all the time until the fat and carbohydrate are nearly finished, but afterwards is used up much more rapidly: in other words, the precious protein is spared as long as possible, and is only used for the purposes of heat and energy when there is nothing else left to use. The man will obviously lose weight all the time, for *intake* is less than *output*.

Now suppose a man is kept in bed for a week, and his diet carefully supervised so that he is given just enough to keep him in health. If he is now allowed to get up and live an ordinary life and do hard work for a week it is plain that he will want more food, and it has been abundantly proved by experiment that *the extra food should be chiefly carbohydrate.*

Salts. Stress has been laid on the fact that our tissues are very complex in their nature, and that carbon, hydrogen, and nitrogen are the chief, but not the only, elements found in them. The other substances, though much smaller in amount, are also essential; if their waste is not replaced by our food, we starve as surely as if we have no food at all, though we starve more slowly. We get our supplies of these substances in the form of salts.

A list of the chief bases and acids which form the salts found in natural waters has been given in Chapter V. A full analysis of the structure of our bodies shows that special bases and special acids are present, and both must be replaced. The following is a list of the most important:

Bases (*metals*).	*Acids.*
Sodium.	Hydrochloric acid.
Potassium.	Carbonic acid.
Calcium.	Phosphoric acid (containing phosphorus).

Remember that these substances are always combined as salts, and that we find, for instance, sodium chloride in the body, and not free sodium and free hydrochloric acid.

We may say, in short, that our food must contain chlorides, carbonates, and phosphates of sodium, potassium, and calcium.

The *chlorides* are the commonest salts, and are found chiefly in the form of sodium chloride or common salt. This salt is found in all our tissues and all our excretions; and from the sodium chloride in our blood there is also manufactured a considerable quantity of free hydrochloric acid which is found in the stomach juices. A considerable quantity of common salt is therefore needed in our food; since this latter is composed of substances very like our own tissues we should probably, if we ate our food raw, obtain sufficient salt without making any addition; salt is, however, lost in cooking, and some addition of table salt is necessary; at the same time most of us have trained our palates so as to like the taste of salt in our food, and most of us take far more salt than is necessary.

In some countries, where salt is sometimes scarce, the people and animals will have a very great craving for it; this is the best proof of its necessity.

Carbonates are found in the blood, and, since these salts are alkaline in nature, they make the blood itself slightly alkaline. If the blood becomes too little alkaline we die; carbonates are therefore necessary to preserve its alkalinity.

Phosphates contain phosphorus, which is found in all our tissues, but more especially in those of the brain and nervous system and also in bone. Phosphorus, however, is not only present in the form of phosphates, but also in the *proteins* of our food; it is probable that wastage of phosphorus in our nervous tissues is replaced by protein and not by phosphates.

Calcium is found particularly in the bones, in the form of calcium carbonate and calcium phosphate. It is very necessary for all of us, but more especially in children where growth is going on and bone is being manufactured.

The uses of salts, and the foods in which they are obtained, will be again referred to later (p. 137).

While speaking of salts it will be well to refer to one or two other substances which are required in our food. These are *iron* and *sulphur*, both of which, like *phosphorus*, are contained in *proteins*. Iron is contained in the haemoglobin of the blood, and sulphur in all the proteins of the tissues. Like phosphorus, too, iron and sulphur can be taken in inorganic forms. Iron is used very largely in medicine, but only a part of that taken in at the mouth is absorbed into the body; much of it simply passes through the body without absorption.

Equally important with the food we eat is the **water** we drink. Life can, in fact, be maintained for a much longer time without food than without water. This is not remarkable in view of the facts that our bodies actually contain 75–80 *per cent., by weight, of water*, and that we continually lose a great deal of water from our bodies, partly in the water vapour in our breath, partly in perspiration, and partly in urine. This water that we lose is obviously not an impurity which has to be got rid of like carbon dioxide, but, none the less, we do constantly lose it, and we shall learn that it serves a very useful purpose while being lost: consequently we need fresh supplies, and the amount we need will be regulated by the amount we lose. The water lost in the breath and in perspiration varies very greatly according to the heat of the day and the amount of exercise we take, much more being lost when it is hot and we are active we shall see later that this loss of water is the chief means by which our temperature is kept at the right level. The water in the urine does not vary so noticeably unless we drink an excessive amount: we get rid of this excessive amount by an increase in the amount of urine passed.

Here we may say the few words necessary about hydrogen, of which we postponed the discussion. The hydrogen in our bodies is converted into *water* when it combines with oxygen: the water so formed is quite

insignificant in amount compared to the water we drink, but still it is bound to make our output of water rather more than our intake. Hydrogen, like carbon, is a valuable heat producer, but is less important than carbon, in a consideration of diet, because its amount is much smaller.

The actual foodstuffs which we eat are not, as a rule, composed of pure protein, carbohydrate, or fat, but are mixtures of these in very different amounts. In many cases we eat actual animal or vegetable tissue, as, for instance, when we eat a sirloin of beef, or a herring, or a chicken, or cabbage, or watercress all these foodstuffs are, as we should expect, mixtures of the various food principles, the animal foods containing chiefly protein and fat, and the vegetable protein and carbohydrate, while all contain salts and water. Very many of our foods, however, are obtained by robbing an animal or plant of food supplies which have been provided for the nourishment of the young animals or new plants, as the case may be. In the animal kingdom we take cow's milk which is really meant for calves, or eggs which are intended for the nourishment of the developing chick, or honey which bees have laid by for their own subsequent use. In the vegetable kingdom instances are even more common: we eat the grain of wheat and not the wheat itself, the potato and not the potato plant, the apple and not the apple-tree. In this class of food we are more likely to find pure food principles: the potato, for instance, is chiefly starch, the white of an egg is nearly pure protein, and the yolk is chiefly fat. Even in this class of foodstuffs, however, most examples are mixtures of the different foods in different proportions: milk, for instance, we shall find to contain all three classes of food, together with sufficient salts and water to provide the young animal with all the nourishment it needs. It is of importance to know the composition of the various foodstuffs we use, so that the value of any diet, or any article of diet, may be fairly judged.

The following table shows briefly what our *intake*, besides oxygen, must consist of:

Food. (i) Nitrogenous material or *proteins* to act as tissue repairers.

(ii) Non-nitrogenous material:

(*a*) *Carbohydrates* } to act as heat and
(*b*) *Fats* } energy producers.

Salts of sodium, potassium, and calcium, and
Water.

Let us now consider some of the actual foods we take, and commence with **milk**, for milk is a food which obviously contains all that is necessary to life, since man and other animals live on nothing but milk in their early lives. The following tables give the compositions, in parts by weight, of cow's milk and human milk.

	Cow's milk.		*Human milk.*	
Protein	3½	Solids 13 per cent.	2¼	Solids 12¾ per cent.
Fat	3¾		3¾	
Carbohydrate	5		6¼	
Salts	¾		½	
Water	87		87¼	
	100		100	

The tables, as is natural, show that the list of substances contained in milk is precisely the same as the list which has been described as necessary to life: milk, however, is not a suitable food *by itself* for adults, for too much has to be drunk to obtain the necessary solid nourishment.

The protein, carbohydrate, and salts are all dissolved in the water, the protein being in two forms—*casein* and *albumin*—and the carbohydrate in the form of a sugar known as *milk sugar*.

The fat, however, which is known as *cream*, is not dissolved in the water, but suspended in the shape of innumerable very small globules each enclosed in a fine membrane, so that the globules are kept separate. The

cream in freshly drawn milk is evenly divided all through, but if the milk is allowed to stand for a time the cream rises to the top, *because fat is lighter than water.* It is the cream which gives milk its characteristic opaque yellowish appearance : milk in which the cream has been allowed to rise, or from which the cream has been fraudulently removed, is a pale semi-transparent fluid with a suspicion of blue in its colour.

On adding *rennet* to milk a formation of *curd* takes place : the rennet acts upon the casein in such a way that it no longer remains dissolved, but becomes a solid undissolved protein : this formation of solid protein takes place all through the milk, and this solid protein, as it forms, *imprisons the fat globules,* so that a solid curd is formed which contains both protein and fat. The remaining liquid which gradually drains away is known as *whey,* and consists of water, with milk sugar and salts in solution. If rennet is added to milk from which the cream has been removed the casein behaves in exactly the same way, but the resulting curd is far less firm and bulky since it does not pick up fat as it forms.

Rennet is obtained from the stomach of the calf: it forms part of the stomach juices and in life performs exactly this same function of curdling milk; it obviously must be present in all mammals, or milk-feeding animals, but, equally obviously, the rennet which deals best with cow's milk is that found in the stomach of the calf.

Cow's milk is a perfect food for the young calf, and human milk for the human infant : as age increases milk is no longer a perfect food, but must be replaced or supplemented by other foods. Cow's milk is, however, a very valuable food for *invalids,* whatever their age may be, owing to its easy digestibility. Further, milk is used in the making of cakes and puddings, and is frequently added to tea or coffee, or taken with porridge, fruit, &c. Not only this, but butter and cheese, which are made from milk, are among the commonest articles of food.

For various reasons many babies are not fed on human

milk, and cow's milk is the common substitute. The tables on p. 107 show that the two milks are not exactly similar; in order to make cow's milk as similar as possible to human milk it is necessary

(1) to dilute with water so as to bring down the percentage of protein,

(2) to add a little cream, and a larger amount of sugar. Pure cow's milk is not easily digested by babies, because the curd formed in cow's milk is much thicker and more solid than that in human milk: the particles of curd are not so finely divided and are, therefore, not so easily digested by the stomach juices. This is certainly the case with ordinary fresh cow's milk, but if this is *sterilized* (see p. 115) the curd is no longer thick and bulky, and the milk can be given to babies without being first diluted: the extra protein is, if anything, an advantage, and babies fed on sterilized whole milk sometimes thrive better than babies fed on sterilized diluted milk.

Milk is an admirable food for bacteria as well as for mankind, and examinations of milk show that bacteria thrive and multiply exceedingly if they obtain access to it: if milk is contaminated by disease-producing germs it becomes a fruitful source of widespread illness. Diphtheria, scarlet fever, and typhoid fever can certainly be spread by milk, and most authorities, at any rate in England, believe that milk can also spread tuberculosis (consumption).

All these facts, then—

(1) that milk, and its derivatives, enter largely into the diet of nearly every one;

(2) that milk is often the chief food of invalids;

(3) that many babies are fed entirely on (cow's) milk; and

(4) that milk is an excellent food for bacteria—

show very clearly how vitally important it is that the milk, which is sold to the public, should be both *rich* and *pure*.

We may say that poor milk is generally the result of dishonesty, and impure milk the result of ignorance or carelessness. Let us consider the two conditions in turn,

the means by which the shortcomings of milk may be detected, and the regulations which govern its sale.

Richness of milk. If a tradesman has 30 quarts of milk to sell for which he charges 3*d.* a quart, he will get 7*s.* 6*d.* for the sale of the whole. If, however, he adds 10 quarts of water to his milk, he will now have 40 quarts of a liquid looking like milk, and which many people will buy as milk. If he sells it all, he will get 10*s.* instead of 7*s.* 6*d.*, and so will make 2*s.* 6*d.* extra profit. The fraud of *watering*, therefore, if undetected, is profitable: it can, however, be detected, as can other methods of weakening milk.

The *lactometer* is an instrument for measuring the 'specific gravity' of milk. The diagram shows the appearance of the instrument, of which the bulb is filled with mercury, so that the instrument will stand up vertically when floated in liquid. The graduations on the lactometer run from 1020–40, from above downwards, and the instrument is merely placed in the milk (which must be of sufficient depth), and the graduation at the surface of the milk read off. 1029 is the average reading of the lactometer in good milk, and 1029 is, therefore, the average 'specific gravity' of good milk. This means that

The weight per volume of milk : the weight per volume of distilled water 1029 1000.

Bulk for bulk, milk is heavier than water, so that if water is added to milk, the specific gravity of the mixture will be *lowered*, the lactometer will sink further in, and the reading will be lowered. Another method of weakening milk is *skimming off the cream.* The cream is the lighest portion of the milk, so that the liquid left behind is *heavier* than pure milk, and the specific gravity is above 1029.

The lactometer, then, will detect either of these frauds if they are done on a big scale. A little consideration will show, however, that the lactometer can be 'dodged' by first skimming off the cream, and afterwards adding water sufficient to bring back the specific gravity to the right level. Milk treated in this way will look thin and

watery, and the fraud can be detected by an instrument known as the *cream measurer.* This is simply a tall graduated cylindrical glass, which is filled up to a certain mark with the milk to be tested and then allowed to stand for twenty-four hours. The depth of the layer of cream formed at the top is read off by means of graduations, and it should be about 8 per cent. of the whole; in any

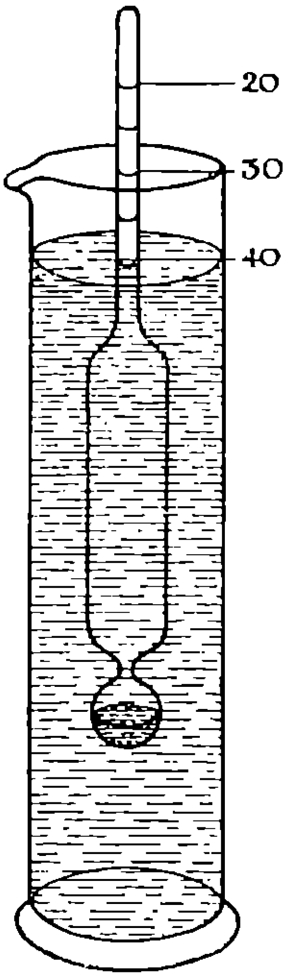

Fig. 23. Lactometer.

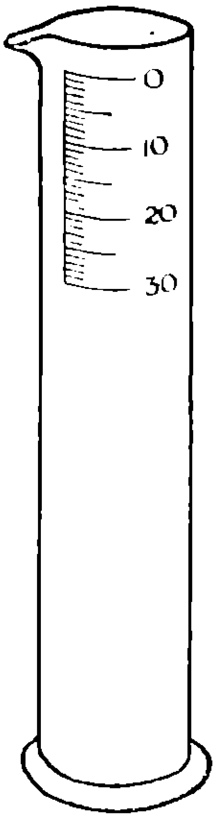

Fig. 24. Cream measurer.

case *not less than* 6 *per cent.* (In very rich milk, such as Jersey or Guernsey milk, the percentage will be 15 per cent. or more, and in Alderney milk may actually reach 40 per cent.) The cream measurer will also expose the fraud of simple skimming. Further testing of milk is performed by analysis, the points specially determined being

(1) The percentage of water.
(2) The percentage of fat.
(3) The percentage of 'solids other than fat', i.e. of protein and carbohydrate and salt.

The average composition of milk is sufficiently variable to make it difficult to detect fraud on a small scale, but the following table shows what results the different kinds of fraud will produce :

	Watering.	*Skimming.*	*Skimming, followed by watering.*
Specific gravity	Decreased	Increased	Unaltered
Water.	Increased	Slightly increased	Greatly increased
Fat	Slightly decreased	Greatly decreased	Greatly decreased
Solids other than fat	Slightly decreased	Slightly increased	Slightly decreased

In any case the fats should come to 2·5 per cent. *by weight*, and the 'solids other than fat' to 8·5 per cent. Note that the percentage of fat by weight is very different to the percentage *by volume* obtained by the cream measurer.

Milk will turn sour in a varying time, this time depending largely on the temperature ; souring is much more rapid in warm than in cold weather. The change is due to the action of a special bacterium, which produces an acid known as lactic acid. Sour milk is both unpleasant and unhealthy for general use. It is, however, used in the manufacture of some cheeses it has also been extensively used recently by doctors in the treatment of some digestive illnesses, particularly in children. As a result, the use of sour milk became a craze among people who either were ill or thought they were ill : the craze is, however, dying out again. Boric acid[1] and salicylic acid are sometimes added to milk to keep it from turning sour, but the presence of these substances can be detected by analysis. Chalk is very rarely added to milk nowadays : it increases the specific gravity of skimmed milk, but it soon settles to the bottom in the cream measurer and is easily detected.

[1] The use of boric acid to preserve milk or cream is perfectly legal, but the percentage of boric acid used must be published so that customers may know of its presence.

To ensure the **purity** of milk—

(1) The cows must be healthy.

(2) The milking must be done under proper conditions, and all receptacles into which milk is placed must be thoroughly clean.

Let us take these considerations in order.

(1) It is certain that disease can be carried in milk drawn from cows with local disease (such as inflammation or ulceration) of the udders, and it is very probable that it can also be carried in milk from cows with disease of other parts of the body. At any rate no hard and fast line can be drawn between diseases which do, and which do not, affect the milk, and it is unsafe to use milk drawn from cows suffering from *any* disease, whether it be local disease of the udder, or general disease of the body. *Tuberculosis* is probably directly transmitted from tuberculous sores on the cows' udders, but it is doubtful whether the germs of *typhoid fever* or *scarlet fever* are ever present in freshly drawn milk, or are always due to later pollution. The same is true of *diphtheria*, but cows suffer sometimes from an inflammation of the udder known as 'garget', which is possibly a form of this disease, and, if so, will transmit the bacteria directly in the milk. Cows also suffer from an epidemic illness known as *foot and mouth disease*, and their milk, when they are in this condition, will cause illness, especially to children.

(2) Perfect cleanliness should be the watchword throughout the various operations of collection and distribution of milk. The cowhouses, the cow's udders, the milker's hands, and the pails must all be thoroughly clean, and the milker should put on a clean overall before milking. Further, all washing of cowhouses, sheds, pails, &c., must be done with pure water, and not with any water taken from a convenient pond or brook. The cowhouses and dairies, too, should not be rough, uncared-for sheds and outhouses, but light, well-ventilated and well-drained buildings, so constructed that they can be quickly and thoroughly cleaned. Neglect of any one of these

precautions *must* lead to more contamination by dirt, and *may* lead to contamination by disease-producing bacteria. It is plain that it is equally important for those who buy the milk to see that it is kept in proper surroundings, and in clean jugs, and that it is only drunk when fresh.

The law endeavours to ensure that milk shall be provided to the public with proper safeguards by imposing various regulations on those who sell milk. The more important of these regulations may be given shortly as follows :

(1) All cowkeepers, dairymen, or sellers of milk must be registered, and their names kept on a list.

(2) Before being registered their dairies and other buildings must be inspected and approved.

(3) The milk sold may, at any time, be examined : if there is evidence of adulteration the seller is liable to punishment.

(4) No person who has, or has recently had, an infectious disease, may have anything to do with the collecting of the milk.

(5) If the medical officer of the district thinks any disease may have been caused by milk he can obtain authority to examine the milk, the dairy, the cowsheds, and the cows. If he finds anything wrong he reports the matter, and the authorities have power to stop the sale of the milk till matters have been put right.

There is no doubt, however, that, despite these regulations, milk is often very far indeed from being pure, though it is far better than it was in former days. When one considers the various details of milking it is clear that a very great amount of trouble and care is necessary to keep milk free from contamination : to keep it absolutely pure is, in fact, *impossible*, and milk, which has not been subjected to the special processes shortly to be described, will always contain *some* particles of dirt and bacteria. In the milk supplied from a well-conducted dairy-farm, however, these contaminations are reduced to a minimum, and such milk may be regarded as reasonably safe, and

as a fit food for anybody. This does not alter the fact that very many dairies are *not* well kept or well conducted, and that disease due to milk will continue until the law is far more strictly enforced.

The subject is by no means simple. Strict regulation and supervision mean increased expense, and increased expense always falls eventually on the consumer. Absolute purity of milk supply would be an immense benefit to the nation, but a rise in price would be a calamity. It is probable, however, that in time the benefit will be more nearly obtained without any accompanying evil.

It is often desirable, when milk is under suspicion, and especially when it is wanted for babies' food, to 'sterilize'[1] it, and so render it absolutely safe. This can be done by two methods.

(1) *Boiling.* The milk is placed in sterilized bottles, and these are stood in water: the *water* is boiled for twenty to forty minutes, and then allowed to cool. The bottles are not opened till the milk is to be used. The taste of the milk is altered, and its composition somewhat changed, but it is probably still equally nourishing.

(2) *Pasteurization.* The milk, in sterilized bottles, is heated to a temperature of about 160° F. for about twenty minutes, and then cooled rapidly. It is found that this is sufficient to kill all harmful germs, and the taste and composition of the milk are hardly altered.

In either case the milk must be quite fresh, for, though sterilization destroys the bacteria, it does not destroy the poisons which they may have already formed in the milk.

As already mentioned (p. 109) sterilized milk produces a much finer curd than ordinary milk.

[1] 'To sterilize' means 'to subject to a process which will destroy all life', and life, in this connexion, practically means 'bacterial life'. Milk, or water, or bottles, tubes, &c., are 'sterile' when they have gone through treatment which makes it certain that any bacteria which were in or on them have been killed. The subject will be further discussed in the last chapter.

Butter is composed chiefly of fat with a small percentage of protein and carbohydrate ; it also contains water. It can be made from whole milk, but is more easily made from the cream which is obtained either by skimming the milk after standing it in shallow pans for twelve to twenty-four hours, or by the use of the apparatus known as the 'separator'. In this latter method, which is the more rapid and the more effective, the milk is placed in receptacles which are whirled rapidly round so that the cream, which is light, collects towards the centre of the revolving apparatus, and the rest of the milk is driven to the margin, where it is allowed to escape. The cream is sometimes used as fresh as possible, but more often is allowed to turn slightly sour, or ripen. It is then placed in a churn, and agitated ; by this means the coats of the fat globules are ruptured, and the fat runs together, forming small particles of butter. When these particles of butter are about the size of grains of sago, the churning is stopped, and the fluid in the churn, which is known as 'buttermilk', is run off. The butter is now washed, in the churn, with water, or if salt butter is being made, with brine. It is then pressed, to get rid of superfluous water, and is afterwards shaped and ready for sale, a little more salt being added if the butter is to be kept. On an average about 22 to 24 pints of milk will produce 1 lb. of butter.

Butter is a valuable food, and provides a large quantity of the fat in an ordinary diet. It is very wholesome when made from pure milk, but may contain any bacteria present in impure milk. If either the butter itself or the cream from which it is made, be kept too long it gets an unpleasant 'rancid' taste. This appears earlier in warm than cold weather.

The two chief uses of butter are to be eaten with bread or toast, or as an ingredient of cakes and puddings. It can be replaced, though the results are not considered so good, by *dripping*, the fat which drips from roasted joints and which is afterwards 'clarified' by melting and

skimming. Dripping is merely another form of melted fat.

Another substitute for butter is *margarine,* made in various ways from animal or vegetable fats, and prepared so as to have the appearance and, as far as possible, the taste of butter. Margarine is cheaper than butter, and is quite a wholesome substitute, though not quite so nourishing : it is illegal to sell it as butter, but perfectly legitimate to sell it as margarine.

Cheese is made from curds, and therefore, if made from whole milk, contains both fat and protein, but, if made from skim milk, contains very little fat. Some of the best-known English cheeses, such as Stilton, Cheddar, and Cheshire, are made from whole milk ; some other English cheeses, such as Somerset, and most Dutch cheeses, are made from skim milk : cheeses made from whole milk are the more expensive. The art of cheese-making is difficult, and requires practice and constant care. In all cases, whether with whole or skim milk, the milk is warmed slightly and rennet added to produce the curd : this is then cut up by long-bladed knives to let the whey escape as easily as possible, and afterwards broken up by a 'curd breaker'; the whey is now all drained away and the curd allowed to turn slightly sour. It is then cut into slabs, and these are afterwards pressed and wrung to form cheeses, which are left for a varying time to 'ripen' (i.e. become affected by harmless bacteria) before being sold.

Cheese is a valuable food since it contains both fat and protein : with bread, which, as we shall see, contains abundant carbohydrate, it is sufficient to maintain life.

Cream is used to strengthen invalids' and babies' milk, and is often prescribed by doctors to patients who are in need of strengthening and fattening. It is very similar in composition to butter, but contains much more water and does not keep so well.

Curds are often eaten fresh, and are sometimes known as 'junket'. They are easily digestible, though not so

easily as milk, and form one of the changes which can be given to invalids who have been ordered a milky diet. Junket is also a pleasant dish for healthy people, and is often eaten with cream, especially in the west of England. Milk is constantly used for milk puddings, which are frequent accessories to both ordinary and invalid diets. It is also used in other puddings, and in cakes and some forms of bread and rolls.

CHAPTER VII

FOOD (*continued*)

SINCE milk is an animal food, it will be well to discuss the other animal foods before going on to those obtained from the vegetable world.

Meat is the name given to the flesh of animals, and it forms the chief nitrogenous food of most people, or, at any rate, of most people who can afford it, for the expense of meat is considerable. Cattle, sheep, and pigs are the animals which give us our chief supplies of meat.

Meat contains an abundance of protein, with a very varying, but always considerable, amount of fat and practically no carbohydrate. The amount of fat naturally depends on the condition of the animal, 'prime beef,' for instance, containing a great deal; even if the visible fat is removed, there is always some remaining between the fibres of the muscles, which make up the 'lean' part of the meat.

The following are the proportions of the constituents of good lean beef, with but little fat showing:

Water	75	parts by weight.
Protein	20	
Fat	$3\frac{1}{2}$	
Salts	$1\frac{1}{2}$	
	100	

Average beef contains much more fat than this. Further, we must note that the average joint obtained from the butcher contains about 20 per cent. by weight of *bone*, and also that about 20 per cent. of the nutritive value

is lost in cooking. This latter loss is more than counterbalanced by the advantages to be described later.

Mutton generally contains rather less protein than beef, and the flesh of pigs, whether in the form of pork or bacon contains more fat not only in a visible form but also between the muscle fibres.

Characters of good meat. Fresh meat will, under ordinary conditions, begin to decompose in a few days, sooner in hot weather than cold, and may then become very dangerous to health. Meat obtained from unhealthy animals is also extremely dangerous, and the flesh of any diseased animal, or of any animal which has died a natural death, should never be eaten.

It is, therefore, very important to be able to recognize the characters of good fresh meat. This should be firm and not watery ; of a good red colour throughout without any paleness, or any suspicion of other colours ; lines of fat should be seen between the big groups of muscle ; and the smell should be fresh and not unpleasant.

It is plain that some practice and experience is necessary before one can recognize the right ‘ firmness ’ and ‘ redness ’ and ‘ freshness ’, but it is a practice which every one should have.

Preservation of meat. There are several ways of preserving meat, before cooking, the most common being *pickling*, *freezing*, and *drying*. In the first the meat is simply left in strong brine, the salt in which acts as a preservative ; the meat is made dryer by this method, as well as more salt. Freezing simply means that the meat is kept continuously cold until shortly before it is wanted ; it is sometimes kept at freezing point, and sometimes a few degrees above this ; in the former method the meat decomposes more quickly after it is thawed than in the latter. Frozen meat is now used largely in England, being sent from New Zealand, Canada, and other places. Frozen meat should, after thawing, look very similar to fresh meat, and freezing, unlike pickling, should not alter the taste and character of the meat.

In drying, the meat is cut into layers, and these are exposed to the smoke from a wood fire ; the method is used very largely for the preservation of fish.

Tinning is a process used for the preservation of meat, after cooking ; it is now used very commonly for all kinds of food ; the tins must be *air-tight,* and must also have *all the air taken out of them.* Unless the greatest care be taken in both these matters tinned food is extremely dangerous, for the presence of air soon leads to decomposition of the contents of the tin : fortunately, some warning is given, as a rule, that things are not right by the facts that (i) the tin is bulging, (ii) when it is opened gas escapes, and (iii) there is an offensive odour. Tinned food is usually quite safe nowadays, but every now and then cases of illness are reported, though there appears to be nothing wrong with the tinning ; in some of these the poisoning has been due to some of the metal, or solder, being dissolved ; this latter risk is abolished by the use of glass, which is now largely employed, but whether glass or ' tin ' be used, the necessity for the exclusion of air remains.

Cooking softens the connective tissue and renders meat looser in texture, more tender and more digestible ; further, it destroys bacteria [1] and also the larger parasites (such as tapeworms, &c.) which are found in diseased meat. These advantages more than outweigh the loss of 20 per cent. of nutritive value.

Roasting and boiling are the two commonest ways of cooking meat. True roasting, before an open fire, is seldom seen nowadays in ordinary houses, but is still used in some large households and institutions ; roasting is now generally done in an oven, and should more properly be called baking. The principle of the two methods (roasting and baking) is the same ; in either case the fire must be even and the heat well regulated. The meat is first strongly heated to cause coagulation of the outside

[1] This action of cooking is not sufficiently strong to make infected meat safe for consumption.

albumin, and so to reduce the loss of the juices from the inside of the meat, and afterwards kept at a rather lower temperature; the lowering of temperature is produced, in true roasting, by moving the meat further from the fire, and in baking by moving it from the top shelf to the lower shelf of the oven. In both cases the joint must be 'basted' from time to time—that is, hot dripping must be poured over it—to keep the joint from burning and to make the distribution of heat as even as possible; in true roasting this latter point is further ensured by suspending the joint on a 'jack' which revolves slowly and continually. The time usually allowed for roasting is twenty minutes for each pound, and twenty minutes over. Too great heat, or too long a time, makes the meat dry and blackened; a fault in the other direction leaves it 'underdone'.

In boiling *for meat,* the joint is first placed in hot water, which is quickly brought to the boiling-point, to coagulate the albumin, and then the temperature is reduced to about 170° F. till the cooking is completed; there should be sufficient water to cover the joint, and the pot should be large enough to hold the joint easily. About a quarter of an hour to the pound should be the time allowed.

Roasting is rather more extravagant than boiling, for, if the latter is carefully done, it allows less of the nutritive value of the meat to be lost; boiled meat is also more tender, but a really well-roasted joint is usually considered the pleasanter and the more palatable.

In boiling *for soup,* or extracts such as beef-tea, where one wishes the water and not the meat to contain the nourishment, the meat should be cut up and put in cold water, where it should be allowed to soak for some time; the water should afterwards be brought to the simmer and kept at this heat for a sufficient time. By this means the meat gives up its protein, *altered in character,* to the water; this altered protein, which is known as gelatine, is not true nourishment by itself, but, nevertheless, it is a protein-sparer—that is to say, if we take gelatine with

our food, we can do with a smaller amount of protein. An extract like beef-tea, therefore, is not a true food, if taken by itself, but is very valuable when taken with other foods ; it also acts as a stimulant to the digestive juices, and increases appetite.

Stewing is a method of cooking which has three very good points. (1) It is economical, for not much of the nutritive value of the meat is lost ; (2) it softens meat so much that some parts can be eaten which can hardly be made palatable in any other way ; and (3) it is a simple method, which wants very little watching. The two chief principles of stewing are firstly that the meat (and vegetables) should be placed in quite a little water so that they may nearly 'stew in their own juices', and a thick gravy be obtained, and *secondly* that the heat should never be great. Meat and gravy are both of nutritive value.

In *frying*, food is heated over a hot fire in a pan containing dripping or other fat ; the fat must be *hot* when the article to be fried is placed in it, so that the cooking is started immediately and the fat at once soaks in. Frying is an extravagant process, and the results are often rather indigestible ; on the other hand it is a quick way of cooking, and often makes the food very savoury.

The stew-pan has been called the 'poor man's friend', and the fryingpan the 'poor man's enemy'.

Poultry and fish. The flesh of chickens and fowls is tender and digestible, but contains rather less protein, and much less fat, than do beef or mutton ; this statement, in fact, applies generally to all white meat as opposed to red meat. Chicken is often given to invalids who are unable easily to digest the stronger meats. Many other birds, including the various game birds (partridges, grouse, &c.), are used as articles of diet, not only because they are good digestible food, but also because they are pleasant to eat and give a change from the larger joints.

Fish of many kinds give a very pleasant, nourishing, and digestible food. Most fish (but not salmon, eels,

or herrings) contain very little fat, and all contain less protein than butchers' meat. Fish, unless it has been preserved, should be eaten *very* fresh, for the flesh begins to decompose quickly, and sometimes gives rise to illness even though it appears perfectly fresh and sound. It is commonly said, because fish contains rather more phosphates than meat, that fish is 'good for the brain'; this is, however, a very vague and inaccurate statement. Many fish are preserved, so that they need not be eaten quite fresh, and thus the vast numbers sometimes caught are not wasted; herrings in particular are preserved both by salting (as bloaters) and by drying (as kippers), and haddock, especially in Scotland, are dried and sold as Findon haddock. Sardines, smelts, salmon, and other fish are sold in large quantities, preserved in tins.

Shell-fish, as a rule, are rather indigestible, and are often dangerous, for they sometimes give rise to obscure poisoning; mussels are, perhaps, the most apt to give trouble. Oysters, however, are extremely digestible, perhaps the most easily digestible of all fleshy foods. The greatest care, however, must be taken to prevent pollution of the sea beds in which they lie. Some epidemics of typhoid fever have been traced to oysters, and careful regulations now govern the keeping of oyster beds. As a general rule oysters are a very safe and valuable food.

As in the case of milk, the sale of meat is carefully supervised by law. It is not necessary to describe the laws, those which govern milk having been given as a type of the way in which legislation endeavours to safeguard the public from dishonesty or carelessness. It may be said, however, that any carcass may be examined by the proper authorities if they are suspicious; should the meat be found to come from a diseased animal, or otherwise to be unfit for human food, the seller is liable to severe punishment. It may also be said that regulations will probably become more stringent in time, especially in the matter of supervision of slaughter-houses.

Eggs, chiefly those of hens, are a very common and a very satisfactory form of food ; unlike meat, eggs become less and less valuable the more they are cooked. Raw eggs are the most nutritious and digestible, but most people do not like the idea of taking them in this state ; beaten up in milk they are, however, frequently ordered for invalids. The white of egg contains (besides water) chiefly protein, with a little fat, while the yolk contains chiefly fat, with a little protein ; the whole egg contains hardly any carbohydrate.

The composition of the whole egg (without the shell) is as follows :

Water	74 parts by weight.
Protein	14
Fat	11
Salts	1

Eggs are best eaten fresh, but are often preserved with success by either (1) coating the shell with some such substance as wax, to prevent the air getting in, (2) boiling for about half a minute to produce a thin coagulation under the shell, for the same purpose, or (3) immersing in lime water. The eggs must be examined from time to time after preservation, for it is common for some to go wrong. A stale egg cannot always be detected, but there are two common and fairly satisfactory tests.

(i) In a solution of two ounces of salt in a pint of water, good eggs sink and stale eggs float.

(ii) A fresh egg, held up to the light, lets the light through best at the centre : a stale egg at the top.

Vegetable foods. After the age of infancy is passed **bread** becomes the chief article of food of most English people ; in England bread is made almost entirely from *wheat.* The wheat grain, as shown in the diagram, is composed of two parts, the small *germ,* which is the part destined to develop into a new plant, and the larger *endosperm,* which is merely a store of food for the developing germ ; the whole is enclosed in an enveloping coat

of two layers. From the wheat grain flour is prepared by milling, and from the flour bread is made. The composition of bread therefore depends very largely on whether the whole, or only part, of the wheat grain is used in the preparation of the flour.

Of the different parts of the wheat grain—

The *endosperm* contains protein, carbohydrate (starch), and salts; the bulk of the endosperm is composed of *starch*.

The *germ* contains protein and fat.

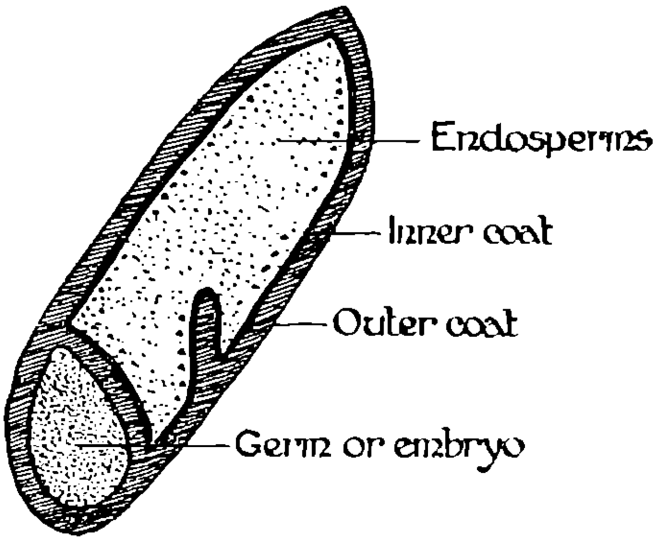

FIG. 25. Diagrammatic section of wheat grain.

And the *outer coats* contain carbohydrate (cellulose) and salts.

The endosperm makes up 85 per cent. of the whole grain, and this alone is used in the preparation of ordinary white flour. Wholemeal flour, which is made from the whole grain, must obviously contain more protein, fat, and salts, and the following table gives a comparison of the two flours.

	Wholemeal flour.	*'Households' white flour.*
Protein	14	10½ parts by weight.
Fat . .	2	1
Carbohydrate	70½	75½
Salts	1	½
Water	12½	12½ ,, ,,

In the making of ' fancy ' bread a flour is often used, obtained only from the central part of the endosperm, which contains less protein than the external parts. Such flour contains about 8 per cent. of protein, and about 76·5 per cent. of carbohydrate.

Now an examination of these tables shows that wholemeal flour and bread comes nearer to the proportions of a perfect food, *in itself*, than does white flour, for the carbohydrate is not so greatly in excess of the protein, fat, and salts.

This being the case, many endeavours have been made to make wholemeal bread popular, and to make it take the place of the common white bread. Against the use of wholemeal bread, however, there have been two arguments raised :

(i) It is not so digestible as white bread, for it contains a considerable amount of cellulose, which is quite indigestible; to some people this may be an advantage, because they need a stimulant to the alimentary canal, but to the majority it merely makes the bread less digestible.

(ii) It is difficult to keep the germ in the flour, because the fat is liable to decompose and turn rancid.

This second argument is easily answered, for there are now several processes by which the germ can be kept in the flour, without making the flour more likely to go bad.

To meet the first argument, another flour is now manufactured, known as ' standard ' or ' 80 per cent.' flour, in which the germ and endosperm are both used, but the outer coats, or bran, are almost entirely left out. Such a flour contains almost all the protein and fat available, but does not contain an undue amount of cellulose.

Let us now consider why it is that people still eat white bread much more commonly than ' standard ' or ' 80 per cent.' bread. The reasons are probably that they *consider* that:

(i) *It is more digestible.* This is not the case, for the indigestible cellulose is present in neither case.

(ii) *It is 'purer'.* In former days there is no doubt that whiteness of flour was a good indication of its purity; it is equally certain that with the present methods of 'bleaching' flour, it is now no test.

(iii) *It is nicer.* This is the real reason, for it takes a very great deal to make people believe that a new bread is as pleasant and good as the bread to which they have been accustomed.

Finally, let us consider the question whether wholemeal or 'standard' bread is really much better for people than the ordinary white bread. We have first to take the case of those people for whom bread is only a part of a varied diet, people who can afford plenty of other food, and secondly the case of those for whom bread is the chief, and often almost the only, article of diet.

It is quite clear that for those in the first class it does not matter what sort of bread they eat; they will naturally use whatever they like best, and they have no difficulty in getting all the nourishment they need. For the poor, however, the question is very different; whatever the nature of the bread the protein is *always* deficient, and there is no doubt that it is much better to make this deficiency as small as possible by eating bread which contains all the available protein, even if the total difference does not seem very great. A great deal of good will have been done when poor people have been taught that the whitest bread is not the most nourishing.

Bread is made from flour in the following manner:

(i) The flour is mixed with water and kneaded to form *dough.* In this process the globulin in the flour is converted into a sticky protein known as *gluten.*

(ii) The dough is charged with bubbles of carbon dioxide. This is done either by the use of yeast (leaven), or baking powder, or by forcing carbon dioxide into the dough by pressure. *Yeast* is most commonly used, and is considered to produce the best-flavoured bread; yeast is composed of innumerable living organisms which multiply and produce carbon dioxide when at a tempera-

ture rather over that of the body; the dough is, therefore, warmed when the yeast is introduced. The passage of the carbon dioxide makes the bread spongy; it is still, however, moist, heavy, and indigestible.

(iii) The dough is now baked in an oven. This kills the yeast and so stops the formation of carbon dioxide, and also drives out much of the gas already in the bread, together with a great deal of the moisture. A hard crust is formed on the outside owing to the extreme drying of this part. Baking makes the bread lighter, dryer, more spongy, and more digestible; the texture should be even and the holes small and close; the presence of large holes means uneven mixing of the yeast.

Bread becomes 'stale' in two or three days, even if kept in tins; the staleness is not merely due to loss of water by evaporation, but also to an actual change in the constituents. Very fresh bread is indigestible (partly because people are apt to eat too much of it), and stale bread is unpleasant: bread is best eaten one day after baking. Very stale bread is not only unpleasant but unhealthy.

When one speaks of bread nowadays, one always means 'leavened' bread—that is, bread which has been charged with carbon dioxide. Unleavened bread can, however, be made, but is tough and leathery and less digestible. The true Scots scone is unleavened, but a little leaven is generally added nowadays. Biscuits, which are made from flour, are unleavened, but go through various extra processes, and have various flavourings added, to make them pleasant and tasty.

Barley, *rye*, and *oats* are somewhat similar in composition to wheat. From the first two, inferior kinds of bread can be made, rye-bread, which is dark and rather sour, being common in some parts of Europe.

Oatmeal contains rather more fat and protein than does wheat flour, and is an excellent food: bread cannot be made from it, however, because its proteins cannot be converted into gluten, and it is chiefly used as food in the

form of porridge and oatcakes. Oatmeal is very largely used in Scotland, and in former days was the chief food of the people ; as a result of this the Scots had one great advantage in their wars with the English, for each man carried, slung on his shoulder, a bag of oatmeal, which, with water, was sufficient to keep up strength and vigour for some days. The English needed more elaborate food, and, consequently, were hampered by the difficulty of carrying it about.

Potatoes are very common and valuable articles of food. They contain a large percentage of carbohydrate (starch) with a little protein, are pleasant to the taste, can be eaten day after day without one getting tired of them, are easily cooked, and are very digestible. They contain too little protein to form a satisfactory diet by themselves, but, nevertheless, they have often been almost the only food taken by many people—especially in Ireland—and have proved themselves sufficient to sustain life.

Rice contains remarkably little water, so that the percentage of food principles which it contains appears large ; as in potatoes there is an excess of carbohydrate and a deficiency of protein. Rice is the chief article of food of many of the inhabitants of India ; melted butter, or some other fat, is taken with it to make up for the absence of fat.

Green vegetables, such as lettuce, cabbage, &c., contain a very great deal of water, and but little true nourishment ; the same statement applies to such vegetables as carrots and turnips. Herbivorous animals such as cattle and sheep have to eat an enormous amount of green food to keep in good condition. Much of the small store of solid matter present in green vegetables is in the form of the indigestible carbohydrate—cellulose. Green vegetables are, however, very useful accessories to a diet, and the same may be said of *fruits,* which also contain very little nourishment, but are both pleasant and useful. The value of green vegetables and fruits lies in the salts and

vegetable acids they contain, and also in the stimulating action of cellulose on the alimentary canal. These uses will be again referred to later.

Peas and beans are rich foods containing plenty of protein and carbohydrate, but very little fat. They are in fact richer in protein than any other vegetable food; the protein, however, is not so digestible as that in the 'cereals' (wheat, &c.)—and a replacement of cereals by peas would soon lead to digestive troubles.

Sugar is pure carbohydrate; it is, therefore, a valuable and digestible heat-producing food, and it is taken with very many of our foods.

Having discussed the purposes which food fulfils, and also the nature of the various foodstuffs which we eat, it remains to consider *how much* and *what kinds* of food we need at different ages and under different conditions.

In the first place, however, it will be well to take note of two ways in which confusion is sometimes caused.

(1) It is very important, when looking at a table which gives the composition of foodstuffs, to notice whether they have been analysed in a *natural* or a *dried* condition. Water forms a large proportion of nearly all our foods, and it is obviously wrong to use for purposes of comparison an analysis of, for instance, natural bread and dried meat; similar mistakes are, however, very often made by students.

(2) Food principles must not be confused with foodstuffs. Meat contains protein and is therefore properly called nitrogenous food; because of this, however, meat is sometimes spoken of as if it were the same thing as protein, and such a confusion can only be the result of carelessness. The great thing is always to remember that nearly all foodstuffs are made up of a mixture of the various food principles, and always to make sure of what is being considered—whether the actual food we eat,

or the various substances on which analysis has shown the values of these foods to depend.

With these two warnings let us proceed to consider what food is needed in a **sufficient diet.**

It should already be clear that this must contain enough protein to replace the daily loss of nitrogen, and enough carbohydrate and fat, or heat-producing food, to replace the daily loss of carbon, and so of heat. For many years physiologists have been at work at the difficult problem of trying to find out exactly what amounts of the different food principles should be contained in the daily diet.

Let us first consider the case of an average man, doing an average amount of hard work.

(1) Very many experiments have been made to determine the daily loss of tissue and loss of heat in such cases —in other words, to determine the *daily output*; it is clear that the *daily intake* should be the same.

(2) Further, experiments have been made with different diets, which represent this intake, to see which diets appear to be most satisfactory.

(3) Many observations have been taken of the food which is taken by ordinary healthy men, living their ordinary lives.

The question is very difficult, and different results have been obtained from time to time, but it appears that the average man, of whom we are speaking, should take about

	100 grammes or	3½ oz. of	**protein.**
	60 grammes or	2 oz. of	**fat.**
and	**500** grammes or	17½ oz. of	**carbohydrate.**

Remember that these figures[1] are only approximate, and that they must be altered under different conditions; some of these conditions we shall discuss shortly.

If now we consider what kinds of English food will contain these amounts of food principles (allowing for

[1] Protein 100 grm., fat 100 grm., and carbohydrate 250 grm., were formerly accepted as the correct amounts.

cooking), we find that the following diet will be roughly correct:

10 oz. good lean beef	animal food.	12 oz. bread	vegetable food.
2 eggs		8 oz. potatoes	
1 oz. cheese		$1\frac{1}{2}$ oz. sugar	
2 oz. butter			
1 pt. milk			

Such a diet will be sufficient and satisfactory for an average man; naturally there are many others, some of them much cheaper, which will do equally well, but it is unnecessary to give any further lists.

Now it has been mentioned that, in Ireland, many of the peasants depend very largely on potatoes for their food, and that in India rice is often the staple food; there is no doubt that in the diet of many of these people there is far less protein than the 100 grammes mentioned above, and yet they can sustain life and health, though vigour is rather lacking. Further, several scientists have deliberately lived for stated times on diets containing much less protein, and have felt no ill effects. Also it is probable that some strict vegetarians do not eat so much protein, and yet remain fit and well. We cannot, therefore, say that 100 grammes of protein daily are *necessary* to life and health, but we may safely say that common experience, supported by scientific experiment, shows that it is a good and sufficient amount for ordinary men.

Many foods are now sold in dry *concentrated* forms, and these are often very useful for short periods. Life cannot, however, be supported for an unlimited time on a few tablets of compressed food a day. Protein is the food which is best compressed, for the amount of protein necessary to replace loss of nitrogen is quite small; there must, however, be a proper bulk of other foods to supply the necessary heat. Dried foods are very useful on expeditions, both because they keep well and because they are much lighter than the natural foods, but an extra amount of water has to be taken with them.

Let us now consider the conditions which alter the amount of food-principles necessary.

(i) **Age.** A growing child or youth needs considerably more food, weight for weight, than an adult, and there are two main reasons for this. The first is that *growth* is taking place—that is, new tissue is constantly being made, and therefore *intake must be greater than output.* The second is that the output itself is proportionately greater in a small animal than a big one—and, therefore, in a child than an adult. This is due to the fact that the proportion of surface (i.e. skin) to weight is greater in a small object than in a big one of the same shape ; the child, therefore, *loses heat more quickly.* This second reason will again be discussed when we deal with the subjects of warmth and clothes. For the present, however, we have the important fact to remember that a child weighing, say, 6 stone, will want *more* than half the food of an adult weighing 12 stone.

(ii) **Work.** Increase of work increases output greatly, and, therefore, more food is needed. As was mentioned in chapter VI, the chief increase should be in *carbohydrate* ; a man doing very heavy work will need 700 or 800 grammes of carbohydrate a day, and for a man doing but little work 300 grammes are quite sufficient. Long sustained heavy work may need a little increase of protein, but never very much.

(iii) **Climate.** Ordinary changes in climate do not affect us very greatly, for we keep our loss of heat more or less steady by altering our clothes and by starting or leaving off fires. A change to a very cold climate, however, necessitates greater heat-producing qualities in our food, and more food, and especially *fat* is desirable ; the Esquimaux in the far north eat enormous quantities of fat. Similarly, in a hot climate, all food, and especially fat, can be reduced.

(iv) **Size.** When discussing the effects of age upon diet, we dealt with the *proportionate* amounts of food necessary. In considering the question of adults of differing size, it is

better to consider the *actual* amounts. Now it is clear that a big man will need more than a small man, but observation shows that it is not so much a question of weight as of *height*; it is really better to say that a tall man needs more than a short. A little careful consideration must show that this *must* follow from what was said on p. 134 about the proportions of surface to weight. Imagine two men of 12 stone weight, of whom one is 6 ft. 3 in. and the other 5 ft. 9 in. in height: in the first man the proportion of surface to weight will be greater, loss of heat will, therefore, also be greater, and a larger intake will be needed.

From time to time the various dangers of the different foods have been mentioned in the foregoing pages; a short summary of them is given below:

(1) *Decomposition* of food, whether in a natural or preserved condition, is always dangerous, and is apt to set up acute poisoning. Sickness and diarrhoea are produced, and these may lead on to death. Illness after eating tinned food is generally due to decomposition, but may be due to

(2) *poison from vessels in which food has been kept.* Besides the cases due to tinning of food, metal (especially copper) is sometimes derived from the pots and pans in which food is cooked.

(3) *Infection by bacteria.* Meat may contain tuberculosis or anthrax germs, and milk may contain those of tuberculosis, diphtheria, or typhoid fever. Oysters may cause typhoid fever, and other examples might be given.

(4) *Parasites in food* may (*a*) produce poisonous substances which lead to illness. The best example is a parasite which grows on rye; the parasite is destroyed in the preparation of bread, but the substance it produces remains, and causes a disease known as 'ergotism'. (*b*) May be eaten and continue to live. The best examples are the *tapeworm,* which is found in meat, especially pork, and another parasite called *trichina,* which is also found

in pork. Good cooking is a great safeguard against these parasites.

(5) *Unexplained causes.* Some foods which are, as a rule, eaten with perfect safety will occasionally cause poisoning, the reason for this being unknown. Various shellfish, and especially *mussels*, will occasionally cause poisoning even though they are eaten perfectly fresh.

Besides the illness definitely caused by eating some particular food, ill effects are produced by *errors of diet.* Overfeeding causes constant strain upon the organs of digestion and excretion, and leads eventually to a state of ill-health and perhaps to such diseases as gout and rheumatism, though these complaints are by no means always due to overfeeding ; too rich a diet brings about the same results as overfeeding. Hurrying over one's food means improper mastication, and therefore increased difficulty in digestion ; hurrying away to games or work immediately after food also causes increased difficulty in digestion, for the blood which is needed, in extra quantity, in the digestive organs is also needed in other parts of the body if they are in action ; consequently the digestive organs suffer.

There are two diseases, the results of errors in diet, which need a longer mention.

Rickets is a common disease in childhood, especially in the poorer classes. It produces a stunting of all growth, and a weakness of the bones, especially the ribs and the leg bones ; this weakness of the bones leads to deformity of the chest and the legs, a deformity which may cripple the patient throughout life. Rickets begins to develop in the period of life which follows infancy—that is to say, when food, other than milk, is first given. It is partly due to insufficient feeding, and partly to improper feeding ; in particular does it seem to be due to giving young children *too much starchy food* (such as bread and potato). Now, rickets is largely preventible, for, though it is sometimes due to poverty or neglect, it is very often due to ignorance. Parents may give their children wrong food,

not because they cannot afford the right, but because they do not know what the right is ; they will often tell a doctor, in answer to a question about diet, that the child has 'just the same as us'. The important thing to remember about a **child's diet** is that, after it is weaned (say, at nine months) *milk should still be the chief food,* but other things should either be added to it or taken with it ; finely made bread and milk, or rusk, or lightly boiled egg, or custard pudding, oatmeal, broth, &c. A little pounded meat may be given occasionally after eighteen months, and later still some finely minced meat and light puddings ; the child is thus gradually led up to an ordinary diet. Even with a carefully chosen diet such as the above, one more point must be attended to ; this is, that the child must not be allowed to stand or try to walk too soon ; it may crawl about without harm, but the erect position puts too great a strain on the bones of the leg.

Scurvy, formerly a terribly common complaint at sea, is due to lack of *fresh* food. It is difficult, even now, to get fresh meat at sea, but vegetables and fruit are more easily kept in the fresh state, and potatoes are admirable preventers of scurvy, or 'anti-scorbutics'. Experience has shown that fresh limes and lemons are very useful indeed, and it is a common thing to serve one ounce of lime juice daily to sailors after they have been ten days at sea. Fresh green vegetables are also good anti-scorbutics.

The value of **fruits and green vegetables** lies largely in the salts and vegetable acids they contain (p. 130). Green vegetables contain a large amount of potassium salts—so much, in fact, that it is wise to eat plenty of common salt with them ; otherwise, the potassium displaces too much of the sodium in the salts of the blood, and so upsets the proper composition of the blood. The vegetable acids found in fruits, such as citric acid (in lemons) and malic acids (in apples), are converted into carbonates, and so help to keep the blood alkaline (p. 104). These

foods are also useful because of their actual bulkiness; they give the alimentary canal, so to speak, something to work upon, and so help the action of the bowels. Lastly, they are excellent foods in hot climates, for they contain very little heat-producing substance, and therefore can be eaten without making the *real* intake—that which is absorbed—too great. A few of these foods, such as rhubarb and figs, have an actual stimulating effect on the alimentary canal.

Accessories to diet. The ordinary man is not content to regard his food as a mere necessary, but wishes also to derive pleasure from it. Consequently he likes his diet varied not only in matter but also in its manner of preparation. The same food can be prepared in many different ways, and can have added to it many different sauces and condiments. To a certain extent there is a true physiological instinct underlying this desire for variety, for the digestive system works best when food is pleasing; this does not alter the fact, however, that plenty of variety can be obtained in good plain food without many sauces or other accessories.

Green vegetables are in a half-way region between true food and accessory food; so also is table salt, for most people eat much more salt than is necessary, because they have grown to like it. *Pepper*, *mustard*, *vinegar*, and other condiments and sauces are pure luxuries; in moderation they stimulate the appetite and promote digestion, but in excess they are harmful.

What has been said about food applies with double force to drink; there are few people who drink nothing but water. *Tea* is very commonly drunk, and some people develop a great craving for it; it should not be strong, and—more important still—it should always be fresh; tea which has stood a long time is very injurious. *Coffee* is another very similar beverage. Both tea and coffee act, in some degree, as stimulants, and are valuable when people are tired and depressed; so marked is this action in coffee that some people find they do not sleep

well if they take it at night. Cold tea is recommended by many Alpine climbers, and others who spend long days of physical effort, as a good drink to carry in one's flask. A cup of hot tea is often found to relieve thirst on a hot day better than a drink of ice-cold water. *Cocoa* is also a good stimulating drink, and contains a little true nourishment in the shape of protein and fat; the actual nourishment is, however, very small in amount, and is really of no account; cocoa, like tea and coffee, derives its value from its stimulating properties. Lemonade, ginger-beer, &c., are simply pleasant luxuries.

The question of *alcohol* is very important from the point of view of hygiene because, whatever may be said about its use by any individual, there is no doubt that anything which will reduce the consumption of alcohol by the nation will be welcomed by hygiene. Drunkards make bad parents, and the children of bad parents do not have the same chances as other children to become good citizens; they are very likely, if they live at all, to become bad parents themselves. Alcohol is, in fact, from a national point of view, nothing but an evil, because if much alcohol is drunk there are sure to be plenty of drunkards. Now let us consider the matter from the point of view of the individual. There are very many men who take alcohol in moderation all their lives, and do not suffer any harm from it; they will say, in fact, that they find it very beneficial, and that it improves their vigour and their capacity for work. There is little doubt, however, that this is merely a matter of *habit*, and the idea that alcohol is of any real value as a food is steadily diminishing; like tea and coffee, however, it is a stimulant, but its effect lasts for only a short time. We may sum up by saying that there is always a danger that any person who takes alcohol *may* become a drunkard, because there are many people who *cannot* resist its temptations; and that there are many who take alcohol all their lives with pleasure and without harm, but that there is no evidence that it does them any good.

Alcohol is also used largely as a medicine, on account of its stimulating properties. It is used both by doctors and by people who have suddenly to help others who have fainted or otherwise become ill. (i) Alcohol is one of the questions on which ‘ doctors disagree ’. There are now many distinguished doctors who believe alcohol is practically useless ; in spite of this the great mass of doctors consider, from their practical experience, that it is, in many cases, a very valuable and sometimes a life-saving drug. (ii) The free use of alcohol whenever anybody feels poorly is a great mistake. There are two good rules to remember when one is wondering whether or no it will be a good thing to give a seriously injured person brandy. (*a*) Do not give it unless the patient can be kept thoroughly warm, (*b*) do not give it unless a doctor can be got in less than half an hour. Another thing to remember is that if a person is very tired, say on a long walk or climb, and asks for brandy, he should not be given it *unless he is nearly home* ; it may be very useful to help him to make the last extra effort, but if he has still a great deal of work in front of him he will be more tired than ever in half an hour.

CHAPTER VIII

DIGESTION, ABSORPTION, AND EXCRETION

Digestion is the process by which the food taken in at the mouth is so altered in its character that it can be absorbed by the blood and so be carried all over the system. Digestion is not all carried out at one place or at one time. We shall find that there are various *digestive juices* which act chemically upon the different food principles: these *chemical* actions are the true essential processes of digestion, but there are also important *mechanical* processes by means of which the food is broken up, softened, and continually moved about so that the digestive juices can have free access to it. No description of digestion is complete if the mechanical processes are ignored. Let us consider the condition of the food from the time it enters the mouth to the time the undigested portions leave the body.

In the **mouth** the chief action upon the food is mechanical. Firstly it is mixed with a fluid called saliva, which softens it, and then the mixture of food and saliva is *masticated,* that is, it is chewed and ground by the teeth till it is well broken up and mixed, and ready to be swallowed; the tongue moves the food about so that all in turn comes between the teeth. Mastication is obviously very important: quite apart from the fact that it is painful, if not dangerous, to swallow a hard unbroken piece of food such as a crust of bread, it is plain that the digestive juices later on will have a better chance of acting upon a finely broken soft pulp of food than upon a hard unbroken portion: people who 'bolt' their food always suffer for it in the long run. Mastication is a *voluntary* movement: that is, it is performed by muscles

which are under the control of the will; it is important, therefore, that every child should be taught the importance of masticating his food thoroughly, so that it may become a habit.

The **teeth**, in an adult, are (or should be) thirty-two in number: those in the front and middle are cutting or biting teeth, and those at the back and sides are grinding teeth. The newly-born babe has no teeth: the first appears when it is about six months old, and by the time it is two years of age there should be twenty teeth. These, however, only last for a time and are known as milk teeth, or *temporary* teeth. When the child is about six years old the temporary teeth begin to come out and be replaced by the *permanent* teeth. There should be twenty-eight of the permanent teeth present by the twelfth or thirteenth year: the last four, which make up the full number of thirty-two, and are known as the 'wisdom' teeth, may not appear for many years; sometimes they do not appear at all. The wisdom teeth are the furthest back of all, and it is noticeable that though they are the last to appear they are very often among the first to decay.

The teeth are made of hard material, and are covered with a coating of a particularly hard substance known as enamel. They are very liable to disease, especially among civilized peoples, and it is plain, since mastication is so important, that a person with defective teeth suffers from a great drawback. It is, therefore, of great importance to take proper care of the teeth, and they should be carefully cleaned, every night and every morning, with a good brush and tooth powder: the substance called precipitated chalk is the chief ingredient in most tooth powders, and is a cheap and very good powder by itself. The cracks between the teeth should also be kept clean and clear by passing fine silk along them. Before and after using the brush the mouth should be well rinsed out. The object of all this is obviously to free the mouth of all traces of food or other foreign matter, and careful attention to the teeth helps enormously towards their preserva-

tion. None the less every wise person will go once a year to a dentist, and have his teeth thoroughly 'overhauled'. If many teeth are missing false teeth should be put in in their place.

The saliva, mentioned recently, is produced by the **salivary glands.** A *gland* is a collection of cells which have the power of *secreting*, or pouring out fluid. In the salivary glands, which are small compact organs, the cells are arranged in clusters and pour their secretion into fine

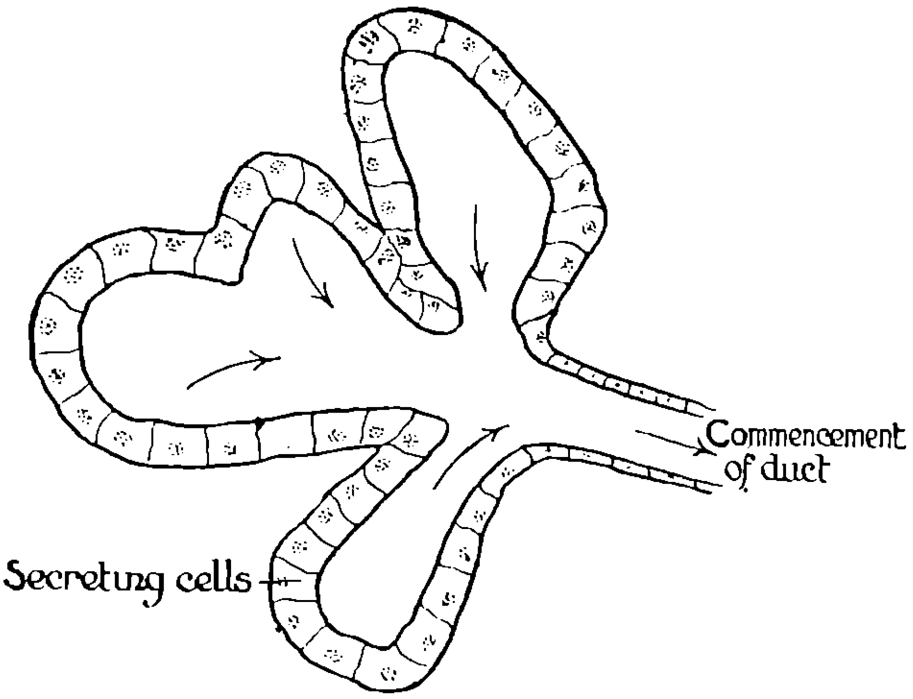

Fig. 26. Diagram of a gland.

tubes, which afterwards unite into one larger tube, or *duct*; the ducts open into the mouth, two in the cheeks and the remainder in the floor of the mouth. The salivary glands secrete saliva as soon as a person tastes, or even sees or expects food; thus everything is made ready as soon as possible for the softening of the food; the common expression of 'food making one's mouth water', is a recognition of the fact that salivation commences as soon as food is seen. Salivation is an *involuntary* secretion, as is the secretion of all the other digestive juices; we have no control over it whatever.

The action of saliva is not only mechanical, though this is its most important function it also acts upon

one class of food, for it has the power of turning starch into a particular form of sugar known as *maltose.* The maltose, as we shall see, is changed into yet another sugar, *glucose* or grape-sugar, before digestion is complete. The saliva, however, *commences* the digestion of starch.

Saliva is a colourless, rather sticky, fluid, slightly alkaline, and consisting of water containing in solution a few salts, and also a ferment called *ptyalin.* It is this ferment which acts upon starch. The word *ferment* needs some explanation, for we shall find that the activity of all the digestive juices depends upon the presence of ferments : in fact, recent discoveries seem to show that ferments play an important part in all the processes of metabolism. Saliva, for instance, without ptyalin has no effect at all upon starch. In composition a ferment is allied to a protein : all ferments have some definite chemical action, and their chief characteristic lies in the fact that, *given suitable conditions, a small amount of ferment will do an indefinite amount of work.* A small amount of ptyalin, for instance, will convert an indefinite amount of starch into maltose if the conditions be kept favourable : what these conditions are we need not enter into, beyond saying that there is always a 'best' temperature : naturally, the ferments in the body act best at body temperature. All the digestive juices, then, contain ferments in solution, and it is the ferments which do the work.

When mastication is finished, the food is ready to be swallowed. Swallowing is a complicated muscular action by which the food is passed by the tongue to the back of the mouth, and then sent rapidly down the gullet to the stomach. Liquids travel very quickly down the gullet, the action of swallowing giving all the impetus needed : solid food is, however, helped along to a certain extent by the muscles in the wall of the gullet itself. The actual swallowing is a voluntary muscular movement, but the muscles in the gullet are not under the control of the will.

There is no special action on the food in the gullet, which is merely a tube leading to the stomach. The rapidity with which liquids travel down it is shown by the fact that when persons take corrosive poisons burning takes place in the mouth and the stomach, but the gullet is generally uninjured.

In its passage down the gullet the food passes the entrance to the windpipe ; if any food gets into the windpipe 'choking' is the result, and the person coughs violently until the food is expelled. Choking is always very uncomfortable and often dangerous, or even fatal, and is most often caused by people talking while they are eating, so that the passage from mouth to windpipe is freely open. There is a piece of cartilage, the *epiglottis*, placed above the opening of the windpipe in such a way that the swallowed food slips safely over it ; it is not, however, closed down like a lid as is often stated. At the same time breathing is stopped, and the windpipe itself is lifted up close under the root of the tongue : this movement of the windpipe is easily felt if any one puts his finger on the front of his throat while he drinks some water, or easily seen if a man's 'Adam's apple' be watched. Here it may be mentioned that the most useful thing to do, if any one chokes really seriously, is to pass one's finger right down the throat and try and dislodge the piece of food.

The gullet takes the food to the **stomach**, and in the stomach an important action takes place. The stomach has already been described as a hollow bag, the walls of which contain muscular tissue : at the junction of stomach and small intestine there is a firm ring of muscle, which effectually stops all passage of food into the small intestine until the proper time. All the muscle in the walls of the stomach and intestines is involuntary muscle ; it is constantly working, but we are neither conscious of it when in health nor have we any control over it. It is only when we have indigestion that we realize that we have any organs inside us at all, for then we get sensations

of *pain* : this pain is usually caused either by some part of the stomach or intestines being too distended or by the muscles contracting very strongly; in either case the fine endings of the sensitive nerves are stimulated.

The inner portion of the walls of the stomach is composed of a sheet of cells, supported by loose connective tissue and

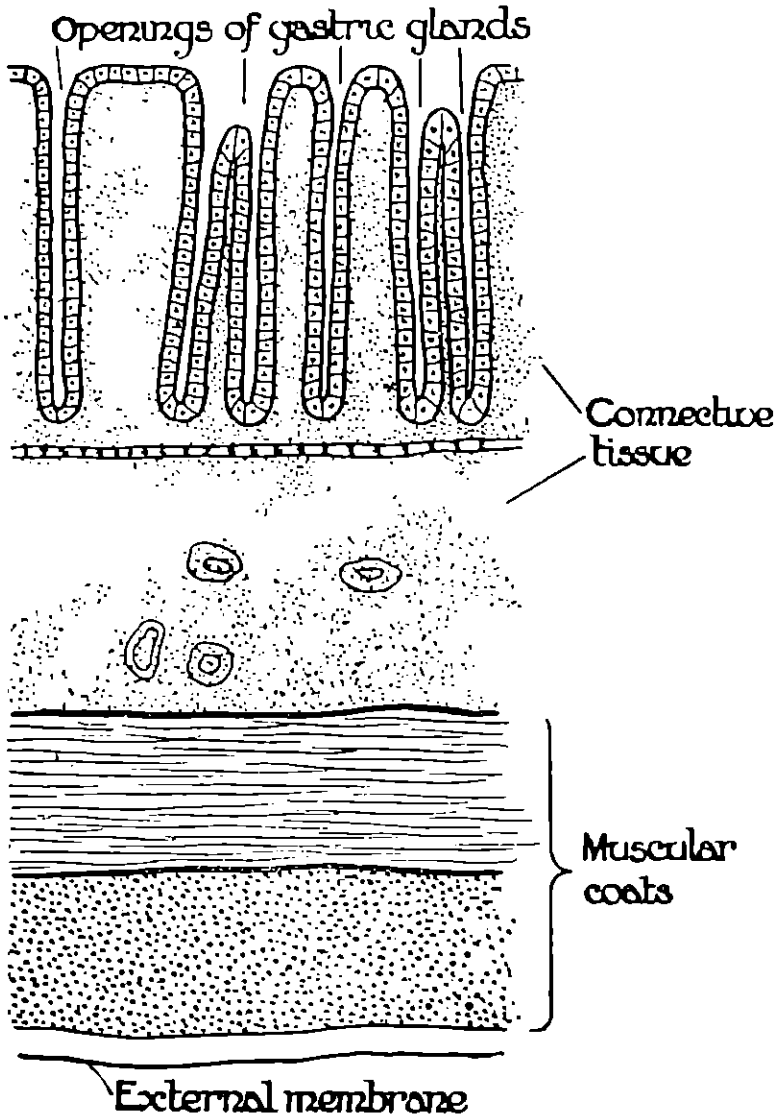

FIG. 27. Diagrammatic section of wall of stomach.

very richly supplied with blood-vessels, forming what is known as a *mucous membrane*. This is not merely a flat unbroken layer of cells, but is pitted with innumerable very fine openings, not visible to the naked eye, but shown by the microscope to be the commencements of fine blind tubes, lined throughout with cells, and reaching down as far as the outer, muscular portion of the stomach wall. Now, these tubes are glands—that is, the cells

which line them have the power of secreting fluid: they differ from the salivary glands in that their fine ducts do not join together and eventually form one large duct, but open directly into the cavity of the stomach. These glands pour out a fluid which is known as the *gastric juice*; the gastric juice, like the saliva, is produced as soon as food is tasted or expected: thus the stomach is prepared for food as soon as it arrives. Unlike the saliva, the gastric juice is *acid*, the acid present being that known as hydrochloric acid. This acid is a compound of hydrogen and chlorine, and, as described on p. 104, one of the uses of common salt in our diet is to provide a supply of chlorine to the blood from which hydrochloric acid may be manufactured. Besides hydrochloric acid the gastric juice also contains two ferments, *pepsin* and *rennin*. 'Rennet' is merely a name for 'an extract containing rennin'; the action of rennin, which is to coagulate milk, has already been discussed (Chapter VI). Pepsin, which is the chief ferment of the gastric juice, has an important action on proteins. Most natural proteins cannot be absorbed into the system, and the digestive juices have to break down those proteins into products which *can* be absorbed. A little consideration shows that during absorption the food must pass through two layers of cells before it can enter the blood-stream, these layers being the mucous membrane lining the alimentary canal and the walls of the capillary blood-vessels. Dissolved substances which are unable to pass through such animal membranes are called indiffusible; the digestive juices change the indiffusible natural proteins into *diffusible* products. The proteins are broken up into a great number of different substances; a full description of these is quite unnecessary for our purposes, and it will be fully sufficient for us to say that proteins are converted, before absorption, into *diffusible products of protein*. If gastric juice is allowed to act on protein for a long time the pepsin will convert it into a variety of these diffusible products, but it is probable that, in ordinary conditions, the action in the

stomach does not go further than conversion to a half-way condition known as *peptone,* which is a soluble and diffusible form of protein; we shall see that peptone is itself further broken up in later stages of digestion.

The action of pepsin, then, is to *convert protein into peptone.*

Knowledge of the action of the gastric juice has led to two methods of attempting to cure people who are suffering from that form of indigestion which is due to poor action of the gastric juice: (i) peptone is given in the diet in place of natural protein, and (ii) pepsin is given by the mouth to aid the digestion of the natural protein in the diet.

The presence of hydrochloric acid in the gastric juice makes it easy to understand that the two ferments, *pepsin and rennin, can only act in the presence of acid.* Indigestion is sometimes due to a deficiency of acid in the gastric juice; it is perhaps more often due, however, to an excess. The acid serves another purpose in acting as an *antiseptic*: that is to say, it destroys many of the bacteria which we eat with our food.

Let us now consider the mechanical action of the stomach. When empty it forms a flat and rather shapeless bag, but after a meal it shows, to a certain extent, the pear shape described in Chapter II. The shape, however, is not constant, for when in use the stomach is never still. The involuntary muscles in its walls are constantly in action, squeezing and churning the food inside so that the gastric juice can get good access to it. Since saliva is alkaline it is plain that its action on starch will be stopped when it mixes with the gastric juice: recent work, however, has shown that despite the churning action of the stomach the gastric juice takes some time to get to the interior of the food in the stomach, and so the saliva goes on acting to some extent on the starch for about half an hour. This is important, for, until it was understood, the action of the saliva was thought to be very slight and temporary.

The stomach muscles move the food about in all directions, but the ultimate result of their action is to drive it down towards the small intestine. The ring of muscle between stomach and small intestine is not open all the time, but only *gradually* allows the semi-digested food to pass on: it first opens about twenty minutes after the food has reached the stomach and then closes again; this is repeated again and again, and in three or four hours the stomach should once more be empty.

The semi-digested, semi-fluid food which leaves the stomach is known as *chyme*; in the small intestine (of which the first part is known as the *duodenum*) it very soon comes under the action of the pancreatic juice and bile, which enter by the pancreatic duct and bile duct (see p. 29). These juices are alkaline, and therefore their first action is to neutralize the acidity of the chyme. When this is done the action of the gastric juice ceases, and the pancreatic juice and bile are free to perform their digestive functions.

The **pancreatic juice** has a powerful action on all three classes of food principle. It is derived from the pancreas, which is a gland similar in its general arrangement to the salivary glands, but with the great difference that, instead of forming a firm compact organ, its clusters of cells are spread out in a long rather scattered organ, which, as described in Chapter II, reaches nearly across the back of the abdomen.

The juice is alkaline and contains three ferments:

(i) *Trypsin* acts upon protein. It not only acts upon any protein which has escaped the gastric juice, but it also carries its action on all protein beyond the stage of peptone, and breaks it down into a number of the simpler diffusible products.

(ii) *Amylopsin* has the same action as the ptyalin of saliva on starch, but is more powerful; the starch is converted into maltose. A very interesting fact about this ferment is that it is not present in the pancreatic juice of infants: this is another proof, in addition to

those gained by experience, that starch is an improper food for babies.

(iii) *Steapsin*, a fat-splitting ferment.

To understand the action of steapsin it is necessary to know rather more about the composition of fats. At the same time it will be wise to consider the functions of bile, for this works with the pancreatic juice in the digestion of fats.

The bile ducts lead from the liver to the duodenum, and the bile is a secretion of the *liver* : the liver is a large and very important organ, and the secretion of bile is only one of its functions.

The **bile** is an alkaline fluid, and differs from the other digestive juices in being of a dark colour : this colour is due to the presence of *pigments*, and it is these pigments which colour the excrement which leaves the body. In the disease known as jaundice this excrement is quite pale : the bile is, however, present in the system instead of getting to the duodenum, and as a result the whites of the eyes, and later on the skin, turn yellow and dark. The pigments in the bile are produced by the breaking down of the haemoglobin in the used-up red corpuscles in the blood. The bile also contains a considerable amount of some special salts of sodium.

Let us now return to the subject of the digestion of fat. The fats in the body are of three kinds, which go by the names of *olein*, *palmitin*, and *stearin* ; the first of these melts at a low temperature, and the last two at a high temperature, higher than that of the body. The mixture of the three, however, which is present in the body melts at a point lower than body temperature, so that the fat in the body is *fluid*.

Fats are found, on analysis, to be compounds of certain acids which are known as fatty acids, with glycerine. These fatty acids are true acids, and are therefore able to combine with alkalies ; the compound of a fatty acid with an alkali is known as a soap. The fatty acids, from which the body fats are derived, are known respec-

tively as oleic acid, palmitic acid, and stearic acid. Remember, then, that

Fatty acid and glycerine = fat.
Fatty acid and alkali = soap.

Fats are *insoluble in water* ; soaps are soluble.

Steapsin, the fat-splitting ferment of the pancreatic juice, has the power of splitting up fat into its component parts of fatty acid and glycerine; fatty acid is therefore set free, and the bile is able to *dissolve* this. Further, the bile and the pancreatic juice both contain alkali, and some of the fatty acid can combine with this to form soap, which is soluble. The bile helps the digestion of fats in other ways also, one of which needs some explanation. If some oil is added to water and vigorously shaken up it breaks up into innumerable very fine drops, which soon come together again : if, however, some alkali be added before the shaking the drops remain separate for a much longer time. When fat is broken up into innumerable fine drops in this way, evenly distributed through the water which holds them, it is said to form an *emulsion*. The best example of an emulsion of fat is furnished by milk, which contains an emulsion of cream when it is fresh. In course of time, as has already been described, the minute particles of fat rise to the surface and form a layer of cream.

The alkali in the bile and pancreatic juice, together with the movement of the chyme, produce an *emulsion of fat in the duodenum*, and the steapsin can obviously act much better on a multitude of small particles of fat than on the unseparated material.

All these changes in the fat lead ultimately to the formation of fatty acid and soap, both of which are soluble and diffusible. Here, however, we get yet another function of the bile ; it has been proved by experiment that these materials will diffuse through an animal membrane more readily if the membrane has been soaked with bile.

Let us now recapitulate the main facts about the digestion of fats :

(1) The acid chyme is neutralized, and made alkaline. (2) The alkali allows the fat to form an emulsion.	Pancreatic juice and bile.
(3) Steapsin breaks up the fat particles into fatty acid and glycerine.	Pancreatic juice.
(4) Some fatty acid is dissolved.	Bile.
(5) Some fatty acid combines with alkali to form soap.	Bile and pancreatic juice.
(6) The dissolved fatty acid and the soap are rendered more diffusible by the action of bile on the wall of the intestine.	Bile.

The bile and the pancreatic juice enter the duodenum (small intestine) from outside organs, but the small intestine produces another juice, the intestinal juice, from glands which lie within its walls. The structure of the intestinal wall is similar, in its broad features, to that of the stomach wall ; a mucous membrane supported by connective tissue, and with a rich supply of blood-vessels, on the inside, and outside this two muscular coats, one with circular muscle fibres and the other with longitudinal. The mucous membrane is pitted with the openings of many glands, as is the mucous membrane of the stomach, but it differs from the stomach in having, in addition, an enormous number of minute finger-like processes projecting into the cavity of the intestine ; these processes are so small that they merely give the membrane the appearance of fine velvet ; they are known as *villi*, and are concerned, not with digestion, but with absorption. From the glands the intestinal juice is secreted this contains ferments which act upon both proteins and carbohydrates. The statement that it acts on proteins requires modification, for natural protein is unaffected, but *peptones* are broken up into the simpler

diffusible products. The action upon carbohydrates is the conversion of maltose, derived from the digestion of starch, into glucose, the sugar which the intestines will absorb: other sugars, including the ordinary cane-sugar, are also converted into glucose.[1]

The intestines also contain a great many bacteria, which have escaped the antiseptic action of the gastric juice, and these have an important influence on digestion, for they help to break up all classes of food into simpler products, many of which can be absorbed. The extent of their action is uncertain; it is probable that, in moderation, it is beneficial, but in excess it is harmful and may give rise to disease. In the course of their action the bacteria give rise to gas, and this in excess causes a very common form of indigestion. Remember that, strictly speaking, these bacteria are not in the body at all: the alimentary canal is only a tube running through from one end of the body to the other, and nothing can get from the alimentary canal to the system proper without being absorbed through the walls of the tube.

The small intestine, like the stomach, is always in motion, and the motion is of two kinds. In the first place there is a constant gentle swaying movement which serves to mix the food and the digestive juices thoroughly, and secondly, there is a very important special movement, known as *peristalsis*, which drives the contents of the intestine gradually from one end to the other. This movement is always in a downward direction, because the involuntary circular muscles in the intestinal wall contract in a wave-like manner, the successive rings of muscle taking up the contraction one after the other and

[1] The intestinal juice contains yet another substance, probably a ferment, whose presence is essential to the action of pancreatic juice. Pancreatic juice in fact does not contain trypsin, but only a *forerunner of trypsin*, until it has come in contact with intestinal juice. It is, however, for our purposes, sufficiently correct to say that pancreatic juice contains trypsin, for this is present as soon as the juice enters the duodenum, and we are concerned with the juice in the duodenum, and not in the duct leading from the pancreas.

always in a downward direction. Absorption takes place all through the small intestine, and therefore the contents at the lower end are chiefly composed of undigested material, remains of secretions, and the wear and tear of the walls of the alimentary canal, with enough water to keep them in a semi-fluid condition. When this material gets into the **large intestine**[1] its progress is much slower; there is little absorption here except of water, so that the contents are little changed except that they become more dry and solid. Eventually they reach the *rectum*, the last part of the large intestine, in a solid but soft condition, and from the rectum they are voided from the body.

The proper action of the intestines is of great importance, and the bowels should be opened regularly once a day. Too frequent an action of the bowels is called *diarrhoea*, and too infrequent an action *constipation*: either condition is a sign that things are not right. Constipation may cause no immediate harm, but good health is more likely to be permanent if regularity of the bowels is ensured. It may perhaps be repeated here, where it may be more clearly understood, that one part of the value of green vegetables and other bulky food lies in the fact that they give the intestines 'something to work on', and so help to make the bowels regular.

Absorption of digested food is effected almost entirely in the small intestine: very little is taken up by either stomach or large intestine. As already mentioned the work is performed by the *villi*, the small finger-like processes, which jut into the cavity of the intestine; these processes average about $\frac{1}{20}$ of an inch in length. When examined under the microscope a villus is seen to consist of a single layer of cells supported by a process of connective tissue. In the connective tissue is a fine network of capillaries lying close to the layer of cells outside them; these capillaries are formed by the divisions of a single small artery which enters at the root of the villus, and they join together again to form a similar small vein which takes

[1] There are no villi in the large intestine.

the blood away from the villus. Another fine tube is also seen running down the centre of the villus ; this is known as a *lymphatic vessel* or *lacteal,* and its further course will be described when its functions are considered. In the meanwhile let us consider the fate of the blood in the small veins that leave the villi ; these join together in the usual way and form a large vein known as the *portal vein.* The portal vein, however, behaves differently to the

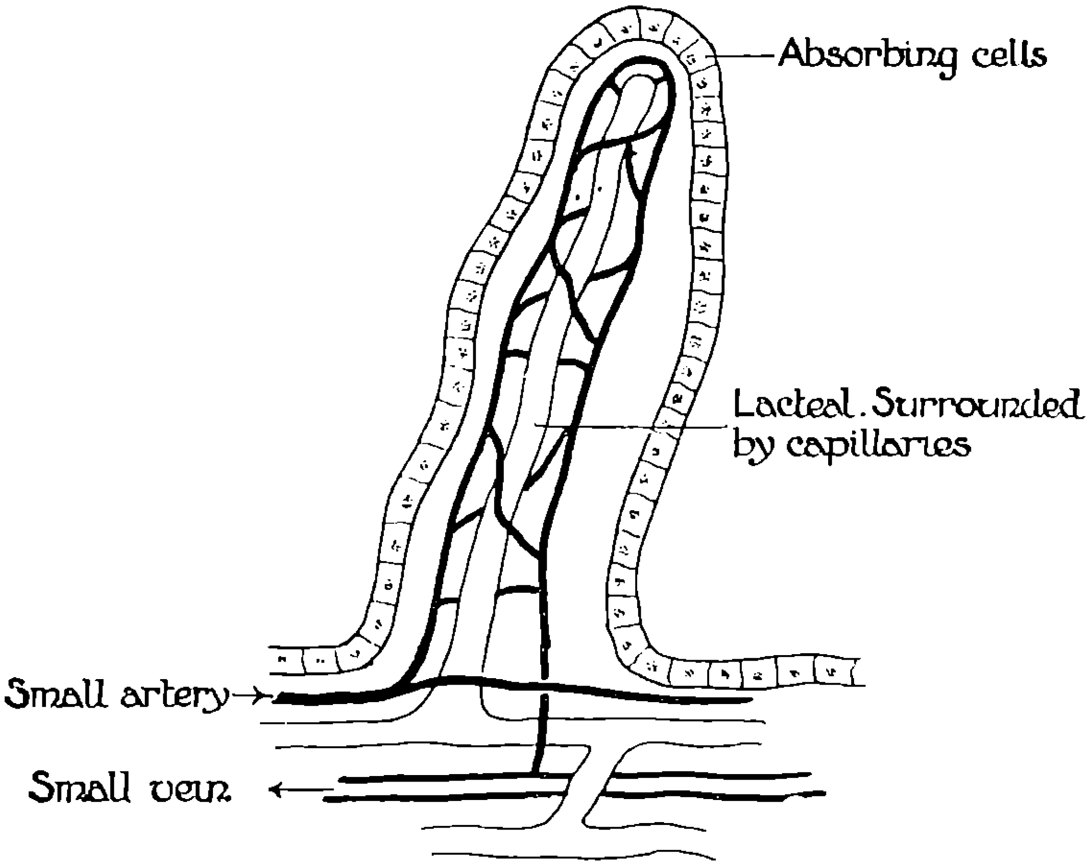

FIG. 28. Diagram of villus.

other veins of the body, for *it runs to the liver and there again breaks up into capillaries.* These capillaries are in close contact with the cells of which the liver is composed ; when they unite again they form the *hepatic vein,* which opens into the inferior vena cava, and so reaches the heart and the ordinary circulations. Thus it is clear that *any substance absorbed by the capillaries of the villi has to pass through the liver before it can reach the general system.* This prepares us for the fact that the liver has an important action on metabolism. The veins from the

stomach and part of the large intestine also enter the portal vein.

Proteins and *carbohydrates* (together with salts and water) are absorbed by the villus capillaries.

The diffusible products of protein pass through the cells of the villi and are *changed back into natural protein* (*albumin and globulin*) *in their course.* How this change is effected is not known, but the evidence that it takes place lies in the fact that no peptone or other diffusible products of protein have ever been found in the blood-stream, but only albumin and globulin : in fact if peptone is introduced into a blood-vessel it actually acts as a strong poison, producing coagulation of the blood, and so death.

The proteins of the food, therefore, appear in the blood as albumin and globulin, and these are carried through the liver to the heart and so to the general system, where they are *assimilated*: that is, as explained in Chapter VI, they are built up into the framework of the various tissues of the body. The blood not only carries protein material *to* the tissues, but also carries disintegrated protein *from* the tissues. Blood containing this disintegrated protein flows through the liver in the same way as it does through other parts of the body, but it is not allowed to pass through the liver without change, for the liver converts the waste protein of the tissues into a substance called *urea.* This substance urea is afterwards got rid of or *excreted* from the body in a manner which we shall presently describe. For the present it is sufficient to say that *urea represents the nitrogenous waste* of the body and that *urea is formed in the liver.*

Carbohydrates are absorbed into the villus capillaries in the form of the sugar known as glucose ; the glucose appears, as such, in the blood, and is carried to the liver. Here a great change takes place for the reason that if there is more than a certain small percentage (0·2 per cent.) of glucose in the general circulation the body suffers from disease, and the sugar is at once excreted by the kidneys,

and therefore wasted. The glucose is therefore *stored* in the liver and given off to the general blood system beyond in such quantities as are wanted. It is stored not as glucose but as *glycogen,* a substance which is neither sugar nor starch but yet is a carbohydrate ; when given up to the blood again it is reconverted into glucose. Glycogen is not found only in the liver, but also in the muscles and some other parts of the body ; the muscles form so very great a proportion of the whole body that the amount of glycogen found in them is appreciable, but, weight for weight, the liver contains far more glycogen than any other part of the body, and it is the liver which regulates the supply of carbohydrate to the body.

The oxidation of the carbon in carbohydrates produces carbon dioxide, and this, as has already been described, is excreted by the *lungs* in the expired air. It has also been mentioned that the carbohydrates can be quickly oxidized, and that they are not so closely built in to the framework of the tissue cells as are the proteins.

Salts and water, like proteins and carbohydrates, are absorbed by the capillaries: the various salts which undergo many transformations and fresh combinations are partly built into the tissues, partly remain in the blood, and partly enter into the composition of the various digestive and other juices of the body : any *excess* of salts in the blood is excreted by the kidneys, and to a lesser degree in the sweat.

Fats, on the other hand, are not absorbed by the capillaries, but by the *lacteal,* which has been described as running down the centre of the villus. The lacteal has a structure somewhat similar to that of a capillary, but its walls are not so complete. The fats are absorbed as fatty acids and as soaps ; glycerine is also absorbed, and *immediately* the fatty acid and soap enter the cells of the intestinal mucous membrane *reconversion into fat* takes place, the fatty acid combining with the glycerine. Under the microscope the minute globules of fat can be seen in the cells ; these globules pass into the lacteal,

which therefore contains, after a meal, an emulsion of fat, the fluid inside it being milky in appearance; this fluid is known as *chyle.* The innumerable lacteals from the various villi join each other to form larger vessels, and eventually the vessels from all over the abdomen open into a small bag which is known as the *receptaculum chyli*; this only means 'receptacle of the chyle'. This bag lies on the right side of the vertebral column, and is therefore right at the back of the abdomen; from it a tube, the *thoracic duct,* carries the chyle away. The thoracic duct runs upwards, through the diaphragm, and right through the thorax, keeping close to the back wall the whole way, and gradually crossing to the left side of the body till it eventually opens, at the root of the neck, into the *left superior vena cava.*

The absorbed fat, therefore, gets into the blood-stream eventually, but by a more circuitous route than do the proteins and carbohydrates also it does not pass through the liver. Fat, like carbohydrate, is oxidized to produce heat, and the carbon dioxide and water which are produced are excreted: a great deal of fat is, however, stored in the body, chiefly underneath the skin and among the muscles. This fat rounds off the shape of the body, and protects underlying parts from injury or from pressure and also helps to keep the body warm: the stored fat is available for oxidation when required, as, for instance, when very hard work is done, or when the diet is too low. A moderate amount of fat is a good thing to have, but many people lay down far too much, making them heavy and uncomfortable and detracting from their personal appearance. As a result there are a great number of 'cures for obesity' advertised in the papers, but the real treatment for fatness is *exercise combined with a low diet.* This will put most people right: at the same time it is an undoubted, and a very interesting, fact that there are some people whose metabolism seems to differ from the ordinary, and who go on laying down fat even when they are on the very lowest of diets.

The three great functions of the liver have now been described. They are

(1) the formation of urea from the nitrogenous waste products of metabolism ;

(2) the formation and storage of glycogen ;

(3) the secretion of bile.

In describing the *structure* of the liver, it is well first to take note of the vessels which enter and leave it. *Entering the liver* are (1) the *portal vein,* carrying blood from the intestines, and (2) the *hepatic artery* derived from the aorta ; for the liver, like any other organ, requires oxygenated blood, and the blood in the portal vein has lost its oxygen while passing through the intestines. *Leaving the liver* are (1) the *hepatic veins,* which are formed by the junction of the capillaries derived both from portal vein and hepatic artery, and (2) the *bile duct.*

The portal vein, hepatic artery, and bile duct all enter or leave the liver at the same place, i.e. the under surface ; the hepatic veins pass out at the back of the organ and enter directly into the inferior vena cava.

The most noticeable point about the structure of the liver is its compactness ; the cells of which it is composed are closely packed and fitted together. These cells are found to be divided up into innumerable clusters known as *lobules,* and each lobule may be regarded as a little liver in itself, for each lobule is supplied by a separate branch of the portal vein and hepatic artery, and each gives rise to a separate branch of the hepatic veins and the bile duct. When we go further and examine the actual cells we find that every cell is penetrated by capillaries derived from these vessels, and also that minute channels appear in every cell and that these channels eventually join to form the branch of the bile duct which leaves the lobule. The main points about the structure of the liver are, therefore,

(i) The whole organ is very compact, the cells being closely fitted together.

(ii) Every cell is in connexion with the portal vein and

the hepatic artery, on the one hand, and with the hepatic veins and bile duct on the other.

(iii) The cells are clustered into small lobules, each of which is in connexion with a definite branch of the above-mentioned vessels.

One more anatomical feature needs mention here; this is that, in connexion with the bile duct there is a hollow pear-shaped sac, about two inches long, known as the *gall-bladder*; the gall-bladder acts as a reservoir from which the bile is expelled when it is needed.

Excretion. Urea is formed by the liver, but it is excreted by the **kidneys.** The kidneys are firm solid organs, the position of which in the abdomen is described in Chapter II. They are joined to the *bladder* by two long tubes, the *ureters.* They are supplied with blood by the right and left *renal arteries,* branches of the aorta, and the blood is taken from them by the *renal veins* which flow into the inferior vena cava. These three vessels, artery, vein, and ureter, enter and leave the kidney at the middle of the concave side, this spot being known as the *hilus.* If a kidney is cut in half longitudinally the expanded upper portion of the ureter is found to open into a cavity inside the kidney known as the *pelvis*; all the outer portion of the kidney is occupied with firm solid tissue. Under the microscope the appearance is very different to that of the liver; instead of showing as a compact mass of cells, the most noticeable feature is an immense number of fine tubules. These tubules run in a very complicated manner through the kidney tissue, but eventually open into the pelvis, and throughout their course, but especially at their blind ends, are in very close connexion with the capillary branches of the renal artery. The work of the kidney tubules is to separate the fluid known as **urine** from the blood in the kidney capillaries. The most important constituent of urine is urea, and thus *the kidneys excrete the nitrogenous waste products of metabolism.* The urine gradually trickles into the pelvis, and from there down the ureters into the

bladder. The bladder, which is a bag with muscular walls, simply serves as a storing place for the urine: from the bladder it is from time to time passed out of the body through the urethra. Thus urine trickles continually into the bladder, but is only passed out of it three or four times a day.

Urine consists of water holding various substances in solution. The kidneys do not manufacture these substances, but merely take them from the blood where they are already present. Far the most important of these is urea, but there is also a small quantity of another nitrogenous waste product, uric acid. Healthy urine also contains some pigment and various salts, the chief of which are sodium chloride and various phosphates. The kidneys may, in fact, be said to excrete anything which is *in excess* in the blood which passes through them: the substances mentioned above appear in the urine in health, but others may appear in disease. For instance, as already described, if the *glycogenic* function of the liver is out of order, and the blood contains more than 0·2 per cent. of sugar, the excess of sugar at once appears in the urine; also the kidneys get rid of many poisons and drugs which may be taken into the system.

The **amount of urine** passed daily varies considerably, but averages about 2½ pints in an adult; the variation depends partly on the amount of fluid drunk and partly on the amount of fluid lost as sweat; hard work and hot weather increase the sweat and diminish the urine. Though the daily amount varies so considerably, the quantity of substances in solution remains very constant; in other words the real nitrogenous excretion of urea and uric acid is much the same from day to day, but the amount of water in which it is dissolved may vary very much.

Characters of urine. Fresh urine is yellow in colour, clear in appearance, and faintly acid in reaction, and has a characteristic smell of its own. The depth of colour varies according to the quantity of water passed; the

more the water, the paler the colour. Under certain conditions the urine may be faintly alkaline, and yet quite healthy.

Though there should be no sediment at all in fresh urine, it is fairly common to see a reddish sediment when the urine has stood for some time and become cool, especially if it is concentrated. This means that things are not completely right, but it does not mean serious disease, and it does not mean 'kidney disease'. This is worth taking note of, for a great many advertisements about the way to cure 'kidney disease' appear in the newspapers, and make many people very anxious and alarmed if they see a sediment in their urine. Remember, then, that this common sediment does *not* signify either diseased kidneys or 'too much uric acid'.

Urine decomposes quickly, and stale urine soon develops a strong and unpleasant smell of ammonia; chambers containing urine should never be left in bedrooms longer than is necessary.

Other channels of excretion. Most of the excretions of the body are passed away as carbon dioxide by the lungs, or as urea and uric acid by the kidneys; the lungs and kidneys are also, under ordinary circumstances, the organs by which the body loses most of its water. There is, however, some excretion also performed by the *skin*; when hot we lose a great deal of water as sweat, and the sweat also contains a trace of urea. When sweating freely, as in very hot weather, we may lose more water in the sweat than in the breath or urine. There is also a little nitrogenous excretion in the excrement voided from the rectum.

It is worth noting here that there is a great difference between the arrangements of the *circulation* for excreting carbon dioxide, and those for excreting urea. In the former case the blood which is fully charged with the gas is taken by a special circulation to the lungs and there purified, both by loss of carbon dioxide and by re-supply of oxygen; the kidneys, however, merely

METABOLISM OF FOOD-PRINCIPLES

	Proteins.	Carbohydrates.	Fats.
Digestion	*Gastric juice.* Protein to peptones. *Pancreatic juice.* Protein and peptones to simpler diffusible products. *Intestinal juice.* Peptone to simpler diffusible products.	*Saliva.* Starch to maltose. *Pancreatic juice.* Starch to maltose. *Intestinal juice.* Maltose and other sugars to glucose.	*Pancreatic juice and bile.* Emulsified and then split into fatty acid and glycerine. Some fatty acid combines with the alkali of the juice to form soap.
Absorption	Peptone and simpler products absorbed into capillaries, but reconverted, during absorption, into albumin and globulin.	Absorbed into capillaries as glucose.	Fatty acid and soap absorbed into lacteals, but reconverted, during absorption, into fat.
Further metabolism	Built into tissues. Excess excreted as urea.	Stored as glycogen, and liberated, as required, to be built (loosely) into tissues. Quickly used up. Partially converted into fat. Excess excreted, unchanged, by kidneys.	Stored in fatty tissues. Excess excreted as carbon dioxide and water, but much excess may be laid down in body (in fat people).
Excretion	As *urea* which is formed in liver (from broken-down tissue material), but excreted by kidneys. A small amount excreted as *uric acid.*	As *carbon-dioxide* formed in the tissues, and excreted by the lungs.	As *carbon-dioxide,* formed in tissues, and excreted by the lungs; and as *water,* in all watery excretions.

receive *ordinary arterial blood,* similar to that which goes to all other parts of the body, and abstract from it the excess of urea.

The preceding table gives the main facts in the metabolism of the three classes of food principles. Remember always that the absorbed materials are built into the tissues, and that their disintegration does not take place in the blood.

CHAPTER IX

PERSONAL HYGIENE

HEAT is constantly lost from the body, because the body is hotter than its surroundings; at the same time, heat is constantly produced within the body by the oxidation of the tissues, and, in order that our body temperature may be kept at the constant level of 98·4° F., it is plain that *heat production must equal heat loss.*

Now, as a general rule, the loss of heat from the body is so rapid that we have a certain amount of difficulty in keeping our heat production up to the right level; this is merely another way of saying that as a general rule we have more difficulty in keeping warm than in keeping cool, or that it is harder to keep our temperature *up* to 98·4° F. than *down* to this point.

Let us, in the first place, consider the more common problem—that of *keeping our temperatures up.* We can attain this end in two ways: (1) *by increasing heat production,* and (2) *by diminishing heat loss.*

(1) We can only increase our heat production by increasing the oxidation of our tissues, and we can do this by taking exercise, or by doing physical work. Common observation and experience support this statement, for every one knows that exercise means warmth; a man takes off his coat and sweater before he plays football on a winter day, and yet he is thoroughly warm in a few minutes; every one knows, too, that the only way to keep warm on a frosty day is to be active and energetic and not to saunter about.

Now it is clear that we cannot be *constantly* active so that we may increase heat production, and it is therefore very important that we should be able to lessen the

necessity for this heat production by having some means of diminishing heat loss.

(2) We may divide these means into (*a*) *natural* and (*b*) *artificial.*

(*a*) Our *natural* means of diminishing heat loss are very limited, but discussion of them necessitates understanding the very important fact that our *sensations* of warmth or cold depend on the condition of our skins; if our skin is warm we feel warm, and if it is cold we feel cold.

Now the condition of the skin depends, in its turn, upon the condition of the blood-vessels immediately underneath it; if these are dilated and full of blood the skin is warm, and if they are constricted and nearly empty the skin is cold. At the same time we must remember that when they are dilated *we lose heat much more freely* than when they are constricted, because the surface of our bodies is so much hotter than the surrounding air. Let us go back for a moment to the man who is going to play football. When he has taken off his coat and sweater he will probably stand about for a minute or two before the game commences, and during that time he will feel cold. This means that his skin is cold, and that the blood-vessels underneath are constricted—*and they are constricted because the body is doing all it can to prevent loss of heat.* When he begins to play, the production of heat is so great that there is no longer any need to lessen heat loss; the body, so to speak, has some heat to spare; the blood-vessels under the skin dilate, heat is freely lost, and the player feels warm. When the game is over he will still feel thoroughly warm, but none the less he will put his things on again, for now that the extra heat production has ceased, heat loss will soon be getting the upper hand again. Our natural means, then, of diminishing heat loss consist in our unconscious power of constricting our skin blood-vessels, and so letting our skins suffer for the good of the rest of our bodies.

(*b*) It is readily seen that if our chance of keeping warm

depended entirely on the vigour of our heat production, and our very limited natural powers of lessening heat loss, we should very frequently be miserably cold. We therefore resort very largely, in fact constantly, to artificial means of lessening heat loss.

(1) We wear clothes by day, and cover ourselves up with bedclothes by night.

(2) We warm our houses either by fires, or by some other form of heating apparatus, and so raise the temperature of the air which surrounds us.

It is because we live under these artificial conditions that we do not need to produce an undue amount of heat, and can therefore carry on our lives in the same manner whether the weather is hot or cold. Remember too that a certain amount of heat from outside is actually obtained by the body when we stand in front of a hot fire, take hot food, or have a hot bath. The lessening of heat loss by artificial means is, however, vastly more important than the occasional receipt of heat from outside sources.

Let us now go on to consider the condition of affairs when the problem is the other way round—when heat loss has to be *increased* in order to keep pace with heat production. This occurs when the weather is hot, so that natural heat loss is slow, or when heat production has been very great as a result of exercise or hard work. Naturally we get rid at once of anything which may artificially hinder heat loss, such as heavy clothes, hot fires, &c., but even so we have to utilize all the natural means of heat loss we possess.

The body loses heat (i) by simple transmission, (ii) by the breath, and (iii) by the sweat. So far we have only spoken of the loss by the first method, which is constantly going on, and which, in cold conditions, we try to reduce. All three methods must now, however, be examined in detail.

(1) Loss of heat by simple transmission is due to the fact that our bodies are hotter than the surrounding air, and this loss is always going on whether heat production

is great or not; the heat is lost partly by *radiation* through the air, partly by *conduction* into the ground or into any object, such as a chair, with which we are in contact, but *chiefly by convection* currents which are constantly set up in the air surrounding us; as described above the only natural means we have of controlling this heat are by the unconscious dilatation or constriction of the blood-vessels of the skin. We can neither sufficiently diminish nor sufficiently increase heat loss by these means alone; to help in the former we resort to artificial means, and to help in the latter we lose heat by the breath and the sweat. Loss of heat by these means is also constantly going on, but the great fact to be remembered about them is that they are especially *means to be used in emergency*, and that they are especially brought into play when there is a risk of heat production being greater than heat loss.

Loss of heat by simple transmission is greatly lessened by the wearing of clothes, because before the body heat can radiate into the air, it has to be *conducted* through the clothes. Now different substances conduct heat at very different rates; for instance, if a bar of iron and an equally thick stake of wood have their ends thrust into a fire, the free end of the iron will get hot very much sooner than the free end of the wood; similarly, on a hot day a metal object will feel much hotter than a bit of wood, and vice versa it will feel much colder on a cold day. In the first case heat is rapidly passed into the hand, and in the second it is rapidly conducted from it. Naturally, the substances chosen for clothing are *bad* conductors of heat; the merits of the various materials used will be discussed later, but we must mention here that the efficiency of clothes in lessening heat loss depends largely on the air which is imprisoned between the different garments, and in their texture, for air is a very bad conductor of heat. This helps to explain the fact that we feel much colder on a windy than on a still day (p. 71), for the rapid motion of the air prevents imprisonment

of air in the meshes of our clothing ; it also helps to explain the fact that leather coats are much warmer for motorists than any amount of wool, for the air cannot penetrate them so easily and so dislodge the air imprisoned beneath. The fur of animals and the feathers of birds have the same effect as do our clothes, and lessen the radiation of heat ; each type of covering imprisons air, and they are both bad conductors of heat themselves. It is a matter of common knowledge that the fur of many animals is thicker and closer and longer in winter than in summer.

(2) Heat is lost by the **breath** for the very simple reason that cold fresh air is drawn into the air passages, and warm air is breathed out again. At the same time heat is lost by the breath because the breath contains water vapour, and the conversion of water into water vapour uses up a great deal of heat ; the more water, therefore, that is so converted in our bodies means the more heat used up and lost. Now, it is clear that we shall lose more heat by the breath when the breathing is rapid and deep than when it is slow and shallow, for much larger volumes of air are passed in and out of our bodies. When we are taking exercise, or doing hard work, or, in other words, when we increase our heat production, the rate and depth of our breathing are both increased, and therefore more heat is automatically lost, and heat loss is in this way given a chance of keeping pace with heat production. Remember, however, that the depth and rapidity of breathing are not increased merely to allow of more heat loss, but also, and *chiefly*, so that the body may have a greater supply of oxygen to make possible the greater oxidation of the tissues.

(3) It is, however, by the **sweat**, or *perspiration*, that the loss of heat is chiefly regulated. The sweat is a secretion of the sweat glands which lie in the skin, and which will be described later, and the loss of heat is due to the *evaporation of the water poured out on the surface of the body*. There is always a little secretion of sweat taking place, but this is so gradual that evaporation can

keep pace with it, and we are not conscious of its presence; when, however, we are hot, and therefore have to increase our heat loss, the glands work more freely, and we are conscious of their action, and can see and feel the perspiration on our bodies. As a result of this we lose heat much more freely, for it is readily seen that the more the water poured out by the sweat glands, the greater will be the evaporation, and, therefore, the more the heat used up. The fact that warmth induces perspiration is very well known to every one, but the effect of this perspiration may be more readily understood by considering the following facts.

(1) When we get out of a bath we dry ourselves with towels not merely because we are in a hurry to be dry. but because we know perfectly well that we shall feel very cold if we allow our skins to dry of themselves. This cold is caused by the evaporation of the water on our bodies.

(2) In the condition known as 'fever' heat production has actually exceeded heat loss, and the temperature of the body is actually above normal. It is common in such cases to find that the skin is hot and dry, and that it is difficult to induce perspiration: if, however, perspiration *can* be induced, it is often sufficient to bring the temperature down to its normal level in a very short time.

(3) It is also instructive to consider the case of an animal such as the dog, which cannot sweat. When a dog is overheated it pants violently, and at the same time hangs its tongue out of its open mouth: in other words, it has to rely on our second channel of heat loss, the breath, and it increases this loss as much as possible by allowing evaporation from the surface of the tongue.

The subject of bodily heat is readily seen to be very wide, and to be closely bound up with other subjects, some of which must now be considered.

Exercise. Apart from its production of heat, exercise is of great value to the body. It increases the rate and vigour of the heart's action, and so strengthens the

circulation ; the blood is therefore driven more vigorously through all parts of the body. At the same time it increases the rate and depth of the respirations, and leads to free expansion of the chest. Now it is a physiological rule that all the muscles of the body can do their work better if they are given plenty of work to do, provided that such work is not so heavy as to overstrain them : exercise, therefore, tends, not merely temporarily, but permanently, to strengthen both the heart and the muscles of respiration, so that they are more fitted for work in the future. The same applies exactly to all the ordinary voluntary muscles of the body, so that plenty of exercise means plenty of vigour in the body generally.

Since exercise means increased oxidation of the tissues, it follows that more food is needed to replace the loss ; not only is more food needed, but the appetite for food is improved, and food taken with a good appetite is more easily digested than food taken merely because it is dinner-time.

Lastly, exercise of the body is a good change from brain-work ; continuous brain-work makes the body sluggish and inactive, and the man who devotes some of his leisure time to brisk exercise will generally enjoy better health than the man who merely does nothing between his times of work.

Exercise may be taken, broadly, in two ways ; either by playing games or in a more set form such as gymnastics, physical drill, &c. It is probable that from a hygienic point of view a combination of the two is advisable.

Games do not merely produce strength, which, in itself, does not make a player 'good at games' ; they also train the eye to work with the muscles, and, by the constant watchfulness needed, and the different and unexpected movements of muscles, make the body supple and active. Further they have the great advantages of being played (as a rule) in the open air, and of giving, to the

majority of people, a great deal of pleasure. One disadvantage of games is that they are of far more value to those who play them well than to those who are either weak or clumsy; the latter derive but little benefit or pleasure from them.

Physical drill and similar exercises have only two advantages over games: the first—and this is important—that they can be as well adapted to the weak and delicate as to the strong and healthy, and the second that they develop the muscles more regularly. Their most important use is to teach children how to 'hold themselves well'; not to slouch and stoop, but to stand erect, and to give their organs, especially the lungs, the best chance to develop and do their work well.

In exercise, as in other matters, moderation is very necessary; too violent or too prolonged muscular work may not only strain the body muscles, but, a more serious matter, strain the heart, which has to work far harder when the body muscles are in use. Physical drill should be very carefully suited to the strength of the children who do it, and, in ordinary life, people should take reasonable care not to over-exert themselves.

Clothes. The chief function of clothes—to lessen the loss of heat from the body—has already been described; they also serve to keep the body dry. Let us consider (i) the rules which should govern the choice of all clothes, and (ii) the different materials of which clothes are made.

(i) In the first place, clothes must be *loose* and *comfortable.* Tight and ill-fitting clothes are a serious disadvantage to a child, for they tend to hinder development, and, if worn for long, may produce actual deformity. The weight of the clothes should be carried by *broad* bands over the shoulders and not from the hips; stockings should be kept up by suspenders rather than garters, and, in any case, the garters should not be tight and narrow. Collars too must never be tight.

Among the various articles of clothing boots and corsets need special mention, for they often give rise to trouble.

Boots are made of comparatively unyielding material, and it is, therefore, particularly important that they should give plenty of room to the feet and not compress either insteps or toes: if they are tight they cause great pain and may produce deformity; in any case they will produce bunions and corns, which cause a great deal of

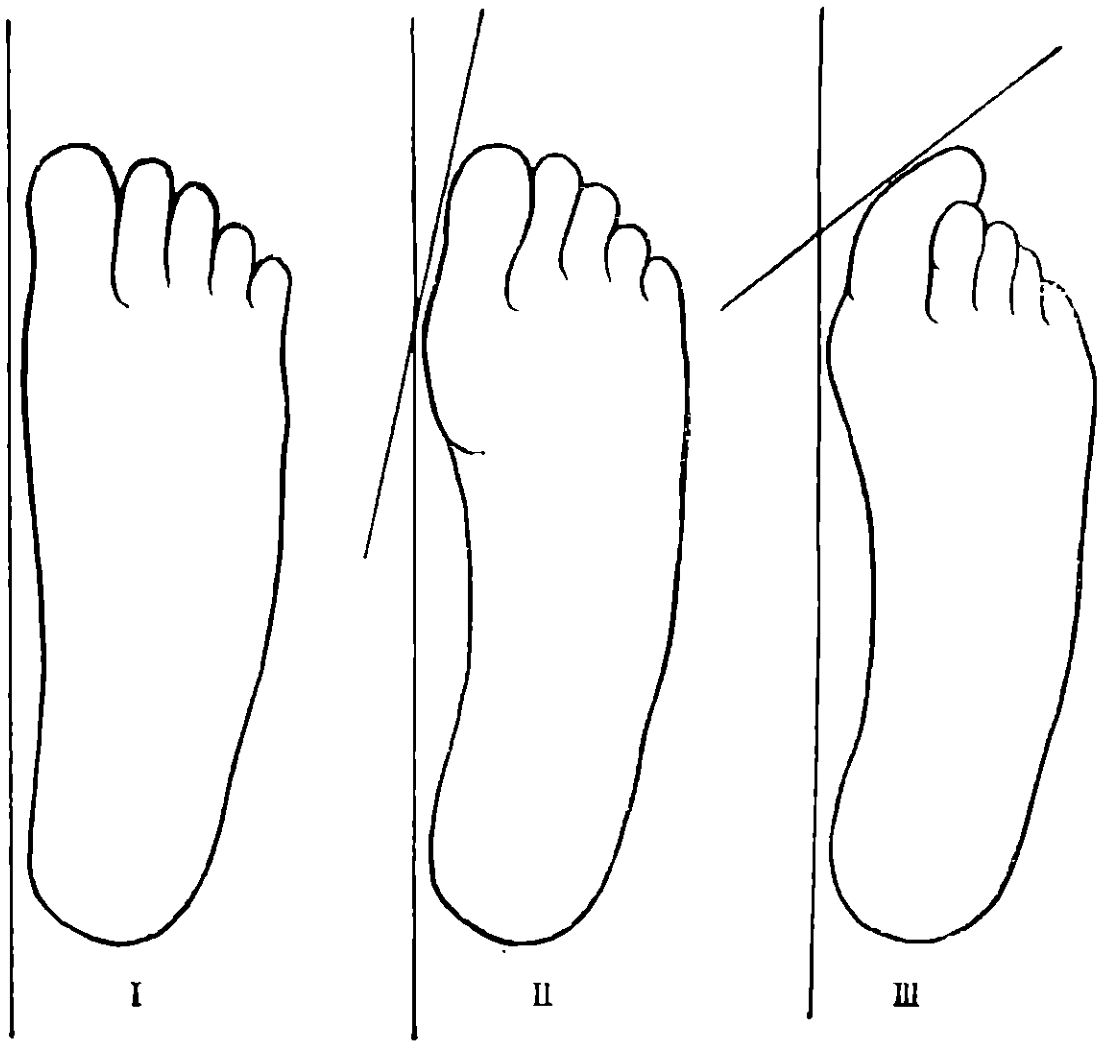

Fig. 29. Diagrams of feet. No. I shows the shape of a foot which has never worn boots. No. II that of the ordinary healthy civilized man who has always worn boots, and No. III an advanced but by no means uncommon stage of the deformity which tight, ill-fitting boots produce.

trouble and discomfort. The toes of nearly all civilized people are somewhat deformed as a result of the practice of wearing boots with pointed toes; the inner side of the boot should really be carried on quite straight to the end. Boots made in this manner look very ugly to our eyes, but this is only a matter of habit, and a great deal of pain and discomfort would be avoided if the fashion of pointed toes could be changed.

At the same time boots should not be made unreasonably loose, or they will cause blisters, and, probably, make the wearer walk in an ungainly shuffling manner.

High heels must also be avoided, as they strain the whole leg through putting the foot in an unnatural position.

A great deal of care should therefore be taken in the choice of boots; similarly, care should be taken in the wearing of them. New boots should never be used freely until the feet have got accustomed to them; it is the height of folly to take a long walk in a new pair of boots. Boots that are intended for rough wear must be thoroughly greased, and all boots must be slowly and carefully dried if they have been soaked. Many people consider it extravagant to have 'trees' on which boots can be kept; 'trees' are, however, very good both for boots and feet, and are economical in the long run, as the boots last for a longer time.

Corsets are extremely harmful if they are either too long or too tight; 'tight lacing' compresses the chest and abdominal organs, and also hinders the action of the *diaphragm*; in a word, it makes nearly all the organs of the trunk work at a disadvantage. Long corsets, too, which reach far up the body are worse than those which only encircle the abdomen and hips; similarly stiff, hard corsets full of steel and whalebone, are more injurious than those which are reasonably pliable.

Babies need warmer clothing than older children, chiefly because their powers of heat production are extremely limited; when they are older and can run about, they produce far more heat as a result of their restlessness and activity. Also it must be remembered, as already described (see p. 134), that they actually lose heat more quickly in proportion to older people. The net result is that, if they are not well covered, their temperature will soon fall and they will die of cold.

Children, though they need less warmth than babies, need more than adults, partly because they lose heat

more quickly, and partly for the same reason that they need more food—because so much of their energy is needed for growth. This latter reason obviously applies to babies as well as to older children.

(ii) The materials of which clothes are made should be *light* and *warm*, that is, bad conductors of heat. The chief materials are woollens, cotton, and linen.

Woollen materials are made from the fleece of sheep, and are, generally speaking, the best. Wool is light and warm, and, another important point, is loose in texture, so that it imprisons air, which, as already mentioned, is a bad conductor of heat. In addition to this, wool absorbs moisture well and does not get wringing wet from perspiration so readily as do other materials.

There are two disadvantages of woollen clothing. One is that it irritates the skin of some people ; this is, however, easily got over by wearing a light undergarment of cotton underneath the wool. The second is that it is expensive ; this is remedied, to some extent, by the manufacture of materials made of a mixture of wool and cotton. Some of these answer their purpose very well, though none are so good as pure wool. One material known as *flannelette* needs special mention, because it is so inflammable that it has been found to be extremely dangerous ; many lives have, in fact, been lost owing to flannelette clothes catching fire. Non-inflammable flannelettes are now manufactured, however, and these form an inexpensive and fairly good substitute for true flannel.

Cotton, which is woven from the down overlying the seed of the cotton plant, is a very light and comfortable material ; for its weight, too, it is warm, though not so warm as wool ; it also falls short of wool in its power of absorbing moisture. Cotton clothes are more likely to become cold and clammy after perspiration. Cotton may well be worn underneath wool when the latter is irritating to the skin, but when wool can be borne it is really best to wear light garments of this material even in summer.

Linen, manufactured from flax, is very similar to cotton in appearance, but its texture is closer and the material is harder. It is more expensive than cotton, and has few advantages over it save that it is finer in appearance and rather cooler in very hot weather, for, of the two, linen is the better conductor of heat.

The *colour* of clothes is chiefly important in hot sunny weather; dark materials absorb radiated heat more quickly than do light materials, and, therefore, on a sunny day dark clothes are hotter than light.

The skin. One of the chief functions of the skin is to produce perspiration; this has already been discussed. The skin has, however, some other important functions, and a short description of it is necessary.

The skin, which covers the whole body, is divided into two well-defined layers—the epidermis or outer skin, and the dermis or true skin. The **epidermis** is composed of a layer, many cells deep, of rather flat cells, *which are not supplied with blood-vessels or nerves*; the function of these cells, which are, in a sense, no longer living, is simply *protective,* and they are constantly being shed, their place being gradually taken by cells from the dermis below. When a blister is formed the outer skin lies outside the fluid, and the true skin underneath; the outer skin can be cut right away without any pain, but the true skin is very tender.

The **dermis**, or true skin, consists chiefly of fibrous connective tissue richly supplied with blood-vessels and nerves; the outer parts project, in many places, into the epidermis as *papillae,* and the deep cells of the epidermis derive some nourishment from the blood-vessels in the dermis.

The skin contains *hair follicles, sweat glands,* and *sebaceous glands.*

The hairs lie in sheaths in the epidermis, and their roots overlie the blood-vessels in the dermis, from which they obtain nourishment. The hairs are not of much use to mankind, though the hair on the head affords some

protection; to animals the hair is of enormous importance, their hairy coats keeping them both warm and dry. Hairs are also very sensitive, and a light touch on

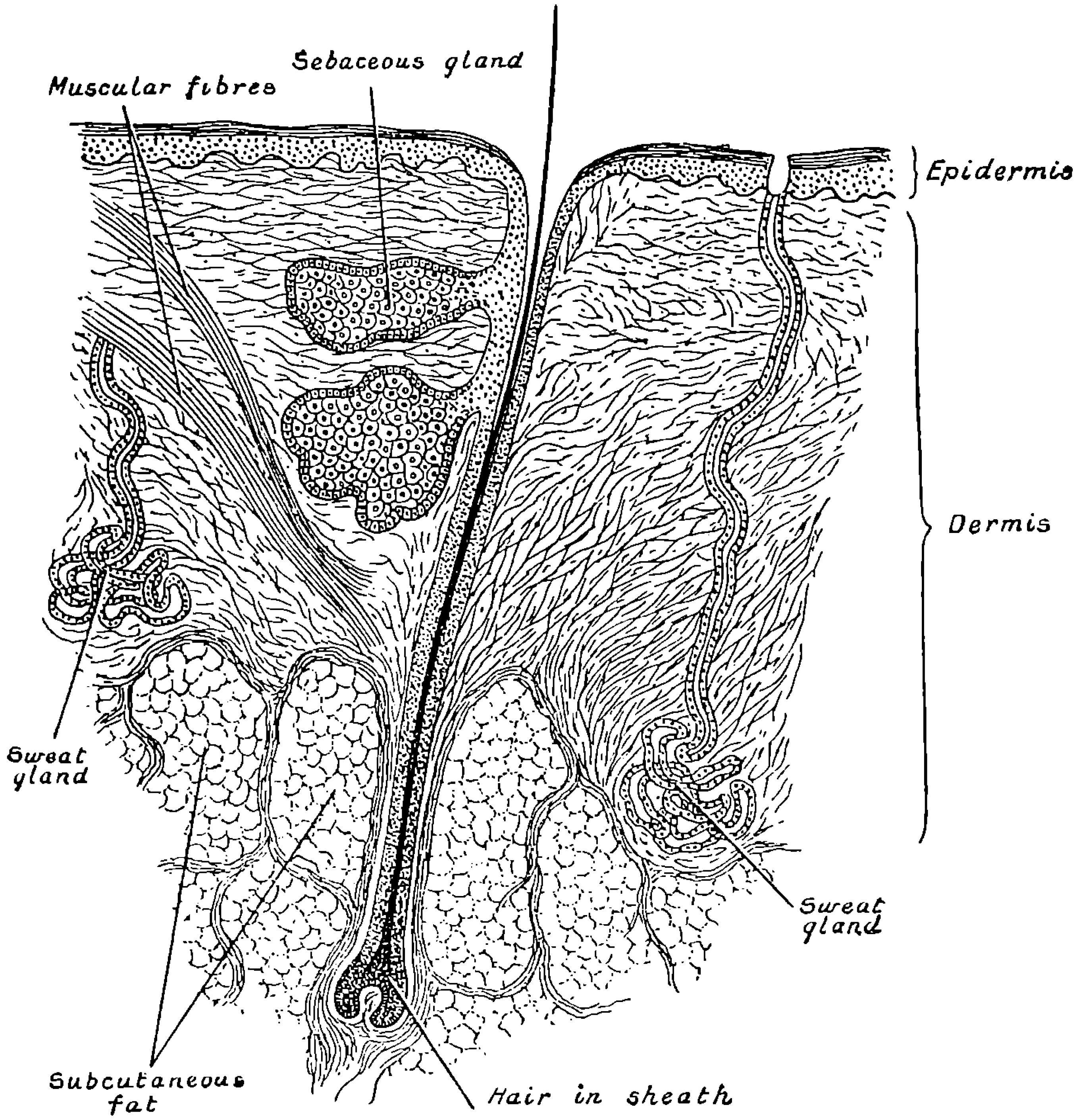

FIG. 30. Diagram of skin.

a single hair, even in man, is easily felt; in many animals some hairs are specially developed for this purpose, e.g. a cat's whiskers.

The *sweat glands* are fine coiled blind tubes, lined with cells, and lying deep in the dermis; they open on the surface of the body by fine ducts which run through the

epidermis; as in all other glands, the cells of the sweat glands are in close association with capillaries. The sweat consists of water, containing in solution a small percentage of various salts, and also traces of urea. The main function of the sweat glands—the regulation of heat loss—has already been discussed; the composition of the sweat shows, however, that they have also a small excretory function, and get rid of a little urea.

The *sebaceous glands* are small blind tubes lying in the epidermis, and opening into the hair-sheaths; they secrete, in very small quantities, a thick oily substance, the *sebum,* which gives the skin its slightly greasy feel; this secretion prevents the skin from getting 'sodden' when it gets wet.

It is readily seen that the skin has many functions. They may be classified as follows

(i) *Protection* of the underlying parts from injury or pressure; this is particularly a function of the epidermis, for the dermis itself has to be protected. The two layers together, however, with the fat underneath them, form a cushion over the sensitive parts underneath.

(ii) *Sensation* (*a*) of *touch,* a function both of the skin and of the hairs in the skin. The sensation of touch is obviously of immense importance.

(*b*) Of *pain,* by means of which we are constantly being saved from injury.

(*c*) Of *heat and cold.*

(iii) *Secretion* (*a*) of *sweat,* by which heat loss is regulated.

(*b*) Of *sebum,* by which the skin itself is preserved.

Personal cleanliness is of great hygienic importance. The secretions of the sweat glands and sebaceous glands make the skin moist and greasy; dirt will, therefore, easily adhere to it, and, mixing with the sweat and sebum, make a sort of 'cake' which will tend to clog the openings of the glands and so hinder their secretions. The dirt is also certain to contain bacteria, and these are able to gain entrance to the body, possibly through unbroken

skin, and certainly through any slight scratch or other injury. In people who are very dirty and careless matters go further than this, for animal parasites, such as lice, &c., will thrive on the skin if left to themselves, and may produce serious illness. For all these reasons it is manifest that both our bodies and our clothes should be fresh and clean. Apart, however, from these more or less scientific considerations, cleanliness is very desirable, and should be a habit with every one. In the first place it is very pleasant; the refreshing and invigorating effect which results from a good 'clean up' after work or exercise may be difficult to describe, but is, none the less, very definite. In the second place, cleanliness renders us more acceptable to our neighbours: a dirty person is bound to be an unpleasant person.

Water is not sufficient by itself to remove the dirt from our bodies; we need something which will act upon grease and so break up the little cakes of dirt which have formed, and soap is almost universally used for this purpose. **Soap** has already been described as a *compound of fatty acid and alkali* (p. 150); it should be used with soft water,[1] so that a good lather is produced, and the skin must be well rubbed with this lather; the soap breaks up into its two constituents, and the grease on the skin is emulsified by the alkali, so that the cake of dirt is broken up and can be swilled away with water. It is most important that toilet soaps should contain no excess of alkali, for free alkali is irritating to the skin; the presence of fatty acid mixed with the alkali enables the latter to do its work without injury to the skin; in many of the best toilet soaps there is an excess of fat used in the manufacture to avoid any risk of excess of alkali, such soaps being known as 'superfatted soaps'. Many toilet soaps contain scent, which, when of good quality, does neither good nor harm, but when of bad quality may be harmful. They may also contain glycerine,

[1] Hot water is more effective than cold because the soap is more easily decomposed, and a better lather is produced.

which gives them a pleasant feel, or disinfectants, such as carbolic acid, which are not usually of much value, or tar, which is of use in some affections of the skin.

For ordinary purposes, however, a plain, unscented, superfatted soap is the best for the toilet. The excellence of a soap depends on the purity of the substances used, and the care taken in its manufacture; it follows, then, that no cheap soap can be really good; it does not follow, however, that a dear soap cannot be really bad, and care must be taken in the choice.

Very cheap soaps are either made of poor materials, or contain an excess of water to increase their weight; in the former case they will irritate the skin, and in the latter they will soon be used up, while in both cases they will fail to give a good lather.

Household soaps are very cleansing in their properties, but are highly irritating to the skin, since they contain excess of alkali; they should, therefore, never be used for washing the skin.

Toilet soaps and the hard household soaps are composed of fatty acid and *soda*, the former containing (preferably) excess of fatty acid, and the latter excess of soda. Soft soaps are made from fatty acid and *potash*.

The *hands* and *face*—particularly the former—are more liable to get dirty than any other parts of the body, and so must be washed more frequently. It is a good habit never to miss washing the hands before sitting down to a meal. The nails, which should always be kept short, require particular attention, for dirt collects under them and is difficult to remove without the frequent use of a nail-brush; the hands themselves require vigorous rubbing, and a brush is often necessary.

The *whole body* should be thoroughly washed in a hot bath at least once a week, plenty of soap being used and plenty of scrubbing with a brush or loofah. The bath should be of a temperature which can be very comfortably borne, for most people about 100° F.[1] The kind of hot

[1] The temperature of a baby's bath should be about 95° F., and should

bath that one can only creep into by degrees is pleasant, but is not healthy, and it is foolish to take baths of this sort, for they are weakening and enervating.

The effect of a hot bath upon the system is to dilate the blood-vessels of the skin ; when the bath is finished the skin remains flushed and warm, and the body will lose heat very rapidly. Unless care is taken, therefore, a hot bath may lead eventually to a chilling of the body ; if it is taken in the morning the clothes should be put on quickly ; if in the evening one should get quickly to bed. A hot bath is often very useful, if followed *immediately* by bed, in inducing perspiration and so checking slight fevers and chills.

Once a week should be the minimum frequency of a good hot cleansing bath ; a daily bath is, however, the ideal. For the young and robust a cold bath, followed by a vigorous rubbing with a rough towel, is to be recommended ; it makes the skin glow, and the bather feel warm and invigorated. It is very certain, however, that cold baths should not be taken by old people or weakly children ; the chill of the water shrinks the vessels of all, and this is not followed by the glow described above unless the circulation is vigorous ; unless one feels thoroughly warm *after* cold baths it is a sign that they should be discontinued, or, at any rate, the chill be taken off.

The *hair* needs great attention : it should be fully combed and brushed morning and evening, and washed or shampooed once a fortnight. Women's hair obviously needs more care than men's, and their hair should be properly dried after washing, or colds and chills may result, to say nothing of tangles and other troubles. It must be remembered that lack of care for the hair is bad for the hair itself, as well as being a source of much dirt and unpleasantness.

always be measured with a thermometer; if no thermometer is available, the temperature can be estimated much more safely with the elbow and arm than with the hand.

The *feet* are often neglected, but ought to be washed properly every day, whether a bath be taken or not. The necessity for taking care of the *teeth* has already been insisted upon (p. 142).

So far we have spoken of cleanliness of the body: cleanliness of the *clothes* is equally important, both for health and comfort, and this applies both to those clothes (collars, &c.) which are visible to other people and those which are worn next the skin.

Lastly we must remember the importance of cleanliness of our *surroundings*; dust and dirt are breeding-places for bacteria, and rooms and houses must be kept scrupulously clean, and the sweepings of dust and dirt destroyed by burning.

Rest and sleep. No part of the body can continue in a state of constant activity, but every part needs periods of rest between its periods of work. This applies even to the heart, and the muscles of respiration; these muscles keep up a constant rhythm throughout life, but the heart rests *between each beat* and the respiratory muscles between each breath. These muscles are adapted for short intervals of work, followed by short intervals of rest, but for the body as a whole it is obviously more suitable for work to be carried on for a comparatively *long* time, and to be followed by proportionately long periods of rest.

As a general rule we work during the day and rest at night.

In life we are constantly receiving impressions from the outside world—impressions of touch, of light, of sound, and the like. These impressions pass up the nerves towards the brain, and when they reach the brain we become conscious of them, and, as a result, we perform the various actions of life. Besides these sensations from the outside world, we have various sensations of the body itself—sensations of hunger and thirst, of restlessness, of desire for pleasure, &c., and in answer to these sensations also the brain directs our various actions.

The various muscles and bodily activities which the brain sets to work all require rest, and this rest is best obtained in sleep, though simple lying down will help a great deal. The brain itself, however, also requires rest, and complete rest for the brain can be obtained *only* through sleep.

The exact nature of sleep is not understood fully ; the one thing certain is that, during sleep, the brain is shut off both from the outside world and also from the rest of the body, so that the two classes of sensations described above do not stir it into consciousness. This statement becomes clearer when we consider our ordinary habits. We go to bed for preference in the dark, to shut out light, and in a quiet room, to shut out sound, and on a comfortable bed, to prevent any particular impressions of touch. Any unaccustomed light or noise, or any roughness in the bed may prevent us from getting to sleep, and in the same way a pain, such as the toothache, will effectually stop sleep ; in other words, we cannot get to sleep *until* the brain is shut off from our various sensations. We merely take the precautions of darkening the room, &c., in order to make all external sensations as small as possible. At the same time we must remember that habit has a great effect upon sleep ; those who are used to it can sleep in the daytime and work at night, and those who have to, are soon able to sleep over a noisy street or near a railway, or under a bell tower.

Now let us consider the waking in the morning ; we are usually awakened by sound—an alarum clock or a knock at the door, a bell at school, or a bugle in a camp. A flash of light, or a shaking, has the same effect. Or we may suddenly wake in the night and find that we are cold, pull on an extra blanket, and drop off to sleep again.

In other words, sensations *can* reach the brain if they are sufficiently powerful, for the brain is still alive ; and if they do, we wake up.

We must remember, too, that the brain itself may be the cause of preventing sleep, even when we do not

appear to be receiving any definite impressions from outside; every one knows that sleep is impossible when we are very worried, or very excited—when, in everyday language, the 'brain is active'.

One fact is known about sleep—this is that during sleep the brain has a diminished supply of blood. This helps to explain why a light meal before bed helps many people to sleep, for the stomach will need more blood than when it is empty, and so the supply to the brain is lessened.

Sleep is of the utmost importance to our welfare; lack of proper sleep leads to tiredness, nervousness, irritability, and, in time, to a general break-down of health. Complete absence of sleep causes death in a few days.

The desire for sleep is one of the most powerful sensations we can have, and will, eventually, overpower all others, though these may, for a time, postpone it; when severely fatigued, men long for sleep more than for anything else, and at such times will risk death itself rather than keep up the effort of postponing sleep.

Different people require different amounts of sleep, and it is impossible to lay down any hard and fast rules. The average adult needs about seven hours in the twenty-four, some more and some less; Napoleon, for instance, is said only to have needed four or five hours, but he is also said to have had the power of dropping off for twenty minutes or so, in snatches, when he felt the need. Babies spend their time chiefly between sleeping and feeding, and the hours of sleep must be very gradually lessened through childhood till the adult times are reached; too long hours of sleep are better for children than too short. In old age rather more sleep is again required.

CHAPTER X

BUILDINGS

Our health depends partly on the vigour of our constitutions, partly on our habits, and partly on the external conditions of our life.

Among these latter, the buildings in which we live and do our work—houses, schools, factories, &c.—must obviously take a very important place.

Let us discuss in detail the factors which make an ordinary **dwelling-house** healthy, or the reverse, and, at the same time, note any special points about other types of buildings.

There are many points which have to be considered in the choice of a house; these may be tabulated as follows:

(1) The nature of the *soil* on which the house is built.

(2) The *situation* of the house: that is, its relation to hills and valleys, the sea, rivers, marshes, &c.

(3) The relation of the house to *other buildings*.

(4) The *construction* of the house itself, including the arrangements for *drainage* and removal of waste matter.

All these are very largely dependent on each other, and all are important; a house may be perfect in every respect save one, and yet be unhealthy through this one failure. We must remember, too, that a house may be good in all respects, and yet be unhealthy through the carelessness of its inhabitants in the matters of ventilation, cleanliness, and the like. In other words, we must know not only how to choose a house, but how to manage it.

Most men are very limited in their choice of a house, partly by their means, and partly by the nature and

whereabouts of their work; they have often, in short, to take what they can get. The chief advantage, however, of the present rapid means of travel—electric trams, tubes, &c.—is that people can now live farther from their work, and consequently have a much wider field in which to choose where they shall live.

(1) **Soil.** All soils contain a certain amount of

(*a*) water (ground water),
(*b*) air (ground air), and
(*c*) organic matter;

and the goodness or badness of a soil, from the point of view of hygiene, is largely determined by the amount and relations of these three.

Ground water. The presence of water in the soil has already been discussed in Chapter V, but some further consideration is now necessary. All permeable soils contain both water and air in their upper parts (see p. 87), but at a certain level below the surface they contain *water only and no air.*

This level is the level of the ground water, and varies in different soils and different places from a few feet to many hundred feet; in a marsh, the level of the ground water is practically the same as that of the ground itself. The ground water extends down to the first impervious stratum, and it is this water which is tapped when shallow wells are sunk; the level of the water in the shallow well is the level of the ground water. The ground water, like any other water, tends to flow down hill, and as much of it as is above the level of the rivers in the open country will gradually get out of the soil into the rivers; according to the nature of the soil, and the arrangement of the impervious strata, the flow will be quick or slow, though it must always be very slow compared to open rivers. Ground water is also taken out of the soil by evaporation; the effect of this is very great when the water is near the surface, but practically vanishes when the water is deep down. Left to itself, then, the ground water would gradually disappear from the

soil, but it does not disappear for the very simple reason that the rainfall is constantly bringing fresh supplies.

It is clear, then, that the level of ground water is affected

(*a*) by the extent of rainfall or drought ;

(*b*) by the ease with which the water can drain away.

If the ground water is *near the surface—that is, within about 15 feet*—the soil is not healthy for building purposes, for both ground and air will be cold and damp ; this is the most obvious danger of ground water. Again, if the ground water is subject to *large and frequent changes in level* the soil will not be healthy ; the reasons for this will become clear when the other matters are considered.

Ground air. Air, as well as water, is found, except in very hard rocks, above the level of the ground water. Loose formations such as sand or gravel contain a great deal of air, and the surface soil, which usually lies to the depth of a few feet over all formations, contains an even greater amount. The air is kept in motion by such causes as the wind, and variations in the temperature and pressure of the atmosphere : the most powerful cause, however, of movement of the ground air is alteration in the level of the ground water.

Organic matter is always found in natural soil, but the soil is amply capable to destroy it and render it harmless in time, chiefly by the action of oxygen. In natural soil the organic matter is chiefly derived from vegetable life, but in the neighbourhood of dwellings the soil may be contaminated by other organic matter due to the near presence of drains, cesspools, graveyards, farm buildings, manure heaps, &c.

The danger of organic matter arises not so much from what is already in the soil when a house is built (except in some 'made soil'[1]) as from the fresh matter, chiefly

[1] 'Made soil' is material of all sorts, generally ashes, old bricks and other refuse, which is 'dumped' into hollows and other places and allowed gradually to settle down and so raise the level of the ground. If only proper material is used and it is allowed a sufficient time in which to purify,

of animal origin, which may pass into the soil underneath the finished house, and it is only this kind of organic matter that will be considered later. Great care must be taken to choose sites which are not likely to be contaminated, and also to reduce contamination to a minimum by careful drainage in the manner to be described hereafter.

Now, it is chiefly the organic matter which affects the hygienic properties of a soil, and *it is the movement of the ground air and water which make this organic matter dangerous to the inhabitants of houses above.* The reason why large and rapid fluctuations of ground water are so unhealthy can now be understood. Suppose the ground water rises a few feet as the result of a heavy fall of rain; it will wash through a thick layer of soil which may contain organic matter in various stages of decomposition; it will dissolve some of this and become vitiated itself, and so may vitiate the water in shallow wells in tho neighbourhood. Remember, too, that it will wash organic matter into rivers; this is one of the reasons why river water is more polluted after heavy rainfall (p. 86). At the same time the ground air, which contains the various gases given off by the decomposing matter, is set in motion; much of it is forced out of the ground into the air above, and so gains access to the houses in the neighbourhood.

A little consideration shows that the question of soil is intimately connected with that of **situation**; it is not sufficient to know upon what soil a house is built, but we must also know where the house is placed.

Let us now discuss the merits of the various kinds of soil, bearing in mind the effects which difference in situation may produce.

The rocky strata such as *granite and slate* are usually healthy because they contain but little air or water.

made soil may be perfectly healthy, but, as a general rule, it must be viewed with great suspicion, for it is likely to contain great quantities of offensive organic matter.

As a rule, the slopes are steep and the surface water runs off quickly. If the rocks are much 'weathered', there is a likelihood of unhealthy patches, for cracks and hollows are apt to be formed which will contain stagnant water.

Clay, on the other hand, is usually unhealthy: there is, as a rule, but little slope, and water will, therefore, neither run off the clay nor through it, for clay is impervious. Both ground and air are likely to be damp and cold.

Chalk and *sandstone* are healthy as a rule, for they are permeable and allow water to drain away freely. They are, however, apt to be mixed with clay, and in such a case will not be healthy unless the slope is great so that water can run off quickly.

Gravel and sand are very healthy, provided the situation be good; a gravel hillock or the upper part of a gravel slope are as good sites as can be obtained, for water passes away quickly, and both soil and air are dry and warm. If, however, the situation be in a hollow which receives water from the slopes above, and, possibly, drainage from houses on these slopes, gravel and sand are among the worst soils instead of the best. They contain a great deal of ground air, and are so easily permeable that, if much organic matter is present, the frequent fluctuations of the ground water are particularly likely to force harmful gases out of the ground and into the air above.

There are several points to be noticed about the situation of a house, apart from those connected with the soil on which it is built.

In the northern hemisphere, houses situated on the south aspect of a slope will be warmer than those on a north aspect, partly because they will be more freely open to the sun, and partly because they will be more sheltered from the cold north winds. Houses on a slope, or on high ground, will have a freer supply of air than those in a hollow; this is not altogether an advantage, for the winds are more violent on exposed slopes, but a house on a high slope sheltered by trees from the north

and east winds is in a very advantageous position. The presence of marshes, river deltas, &c., in the neighbourhood tend to make the air cold and damp. Trees must not be allowed sufficiently near a house to interfere appreciably with the light, or with the free circulation of air ; at a sufficient distance trees are very pleasant, not only because they afford shelter, but for the sake of their appearance. Remember, however, as mentioned in Chapter IV, that the presence of forests increases the moistness of the air.

The relation of a house to **other buildings** also requires consideration. A detached house is the most desirable of all, for there is air on every side, and there may be windows in every wall ; it is also more comfortable, for there is less chance of disturbance by one's neighbours. There is no reason, however, why houses in rows should not be perfectly healthy. It is better for such rows to run in a north and south direction ; the houses will then face east and west, and every room can get its share of either morning or evening sun. The side walls of these houses should run right up to the roof, and there should be no communication between the air-spaces which are left between the roofs and the top rooms of adjacent houses.

Though the sides of houses may be touching, it is very important that there should be free space both in front of and behind every house, and the length of this space should be at least *equal to the height of the house,* or the house will not get its fair share of air and light. Back-to-back houses are thoroughly bad, not only because of the absence of light and air, but also because it is much more difficult to secure good drainage. Courts and small squares are also undesirable, for fresh air and light are limited. The same applies to small houses built in the shadow of large and tall buildings ; people who have to do without their fair share of fresh air and sunlight are at a disadvantage, and are more likely to be ailing.

Pigstyes, cowsheds, cesspools, &c., and places where

offensive trades are carried on should never be allowed near a house, for not only is the smell unpleasant and trying, but the air may be contaminated with injurious gases ; clearly, this matter is of even greater importance when the household depend for their water supply on a well sunk near the house.

One or two points must be noticed about the individual rooms in a house. The living-rooms should, if possible, face south or south-west, so as to get a full allowance of

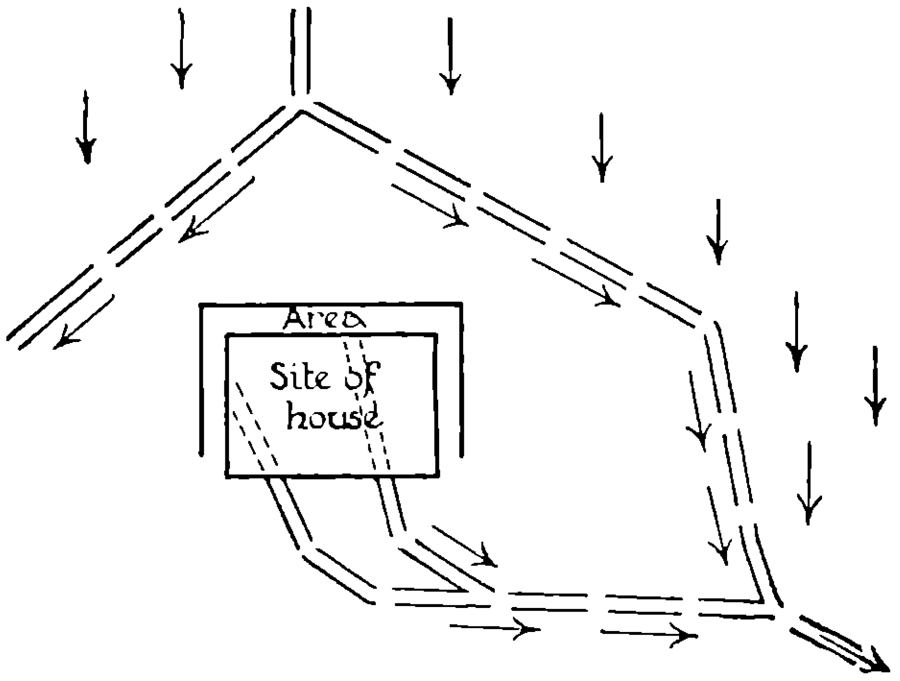

Fig. 31. Diagram to show a manner in which a house built on a slope can be protected from damp by subsoil drainage. The soil underneath the house must also, as shown in the diagram, be drained.

sunshine. The same applies to invalids' rooms ; if this aspect is not possible, remember that a west aspect is better than an east, for the evening sun will cheer and enliven a patient, while the morning sun will tend to wake him up early.

Improvement of sites. A well-constructed house goes far towards counteracting the bad influences of soil and situation ; naturally, however, as good a site as possible must be chosen, and, further, all that is possible must be done to remedy the faults of any site selected. The first and most obvious thing to do is to clear away,

if possible, any causes of contamination of the ground with organic matter. Besides this it may be necessary to drain the soil, to prevent excessive dampness or excessive fluctuations of the ground water.

If the site is on the lower part of a slope, or in a hollow, the drains must be so constructed as to direct the water from the slopes above to one or both sides of the house, and also, if in a hollow, to let the water get away altogether. This *subsoil drainage*, which must not be confused with the drainage of waste matter from the house itself, is carried out by digging trenches, laying at the bottom loosely-connected unglazed porous pipes, and covering the trenches in again. Specially damp places may be filled in, or specially drained. Large sites can be permanently improved by drainage of this sort before any building is commenced, and small sites can be further improved, if necessary, by laying down fresh soil to fill up small hollows, &c.; gravel is the best for this purpose, but the expense is great.

House construction. The first essential in a house is *stability*; the walls must be sufficiently thick and well built, and the foundations sufficiently deep, to render the house safe in any conditions of weather: the side walls are founded on a base or ' footing ' which is at least one-and-a-half times as wide as the wall itself, so as to distribute the weight of the house over a wider area. See Fig. 32. In the second place, a house must be *dry*. Rain may enter through the roof and sides, and ground water may enter through the sides and foundations. In the third place a house must be *warm*.

Let us consider first the means taken to prevent the entrance of ground water, for it is not sufficient simply to build the house of good brick or stone. This is clearly shown by the simple experiment of placing a pile of, say, four bricks in a vessel of water not deep enough to cover the bottom brick. In course of time the uncovered bricks all become damp, for the bricks are porous, and the water rises through the pores as a result of the force

known as ‘capillary attraction’. If a very fine tube of glass be placed with its tip just under water, the water will immediately rise in the tube for a distance which varies with the fineness of the tube; the finer the tube, the further will the water rise. In the same way the water rises in the innumerable fine channels produced by the porous nature of the bricks, and will pass from brick to brick. If, however, the third brick in the pile of four is a *glazed* brick, it is found that the top brick, the

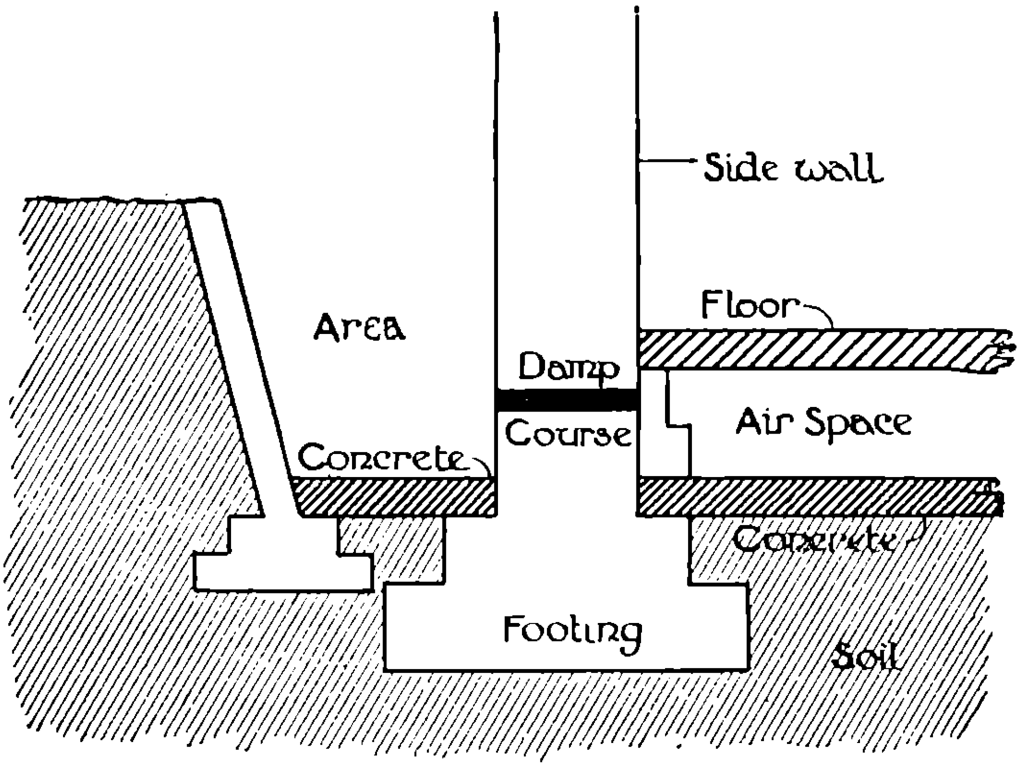

Fig. 32. Damp course.

fourth, remains dry. The pores of the glazed brick are closed by the glaze, and ‘capillary attraction’ is no longer possible; a glazed brick is, in fact, practically *impervious.*

Other materials, such as slate and concrete, are also nearly impervious, and the use of these materials in certain important places goes far to make a house dry. Careful examination of the two diagrams (Figs. 32 and 33) will show how these materials are used, so as to keep out the ground water both from the foundations and the side walls of a building.

In the first place note that the floor of the lowest rooms

is not built right down on the foundations, but that there is an air space underneath it, and that below this air space is a solid bed of concrete. If the house contains cellars, these will remove the need for a special air space, but whether there are cellars or no cellars, an air space must never be omitted ; this air space must be ventilated.

Note, secondly, that in each case there is a layer of impervious material, such as slate, asphalt, or glazed brick, *built through the full thickness of the wall*, at a point a little

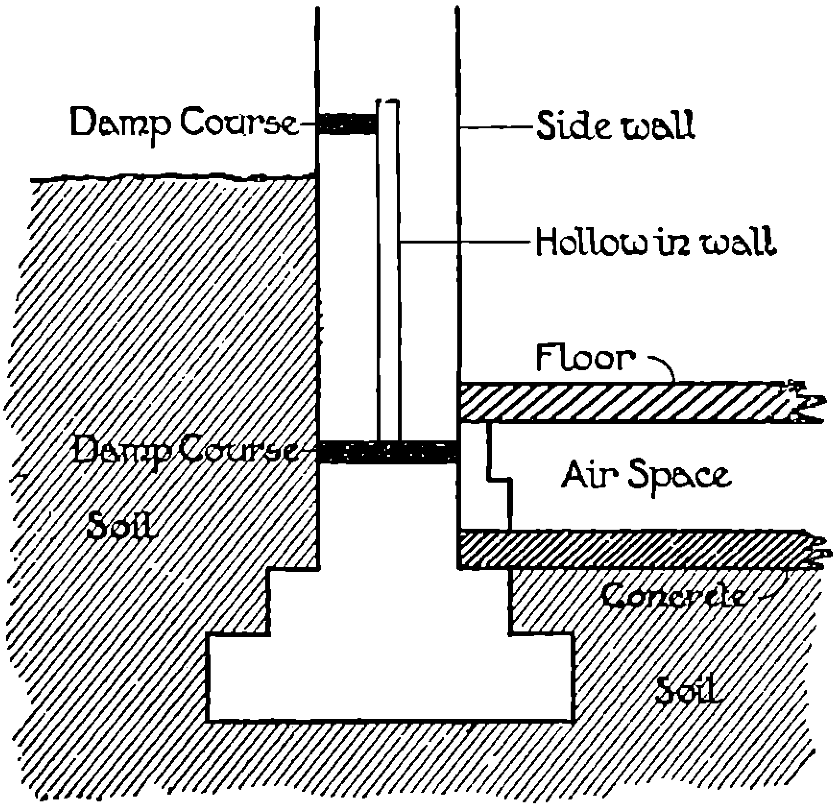

FIG. 33. Double damp course.

below the level of the lowest floor. Such a built-in layer is known as a *damp course.*

The diagrams also show two methods of protecting the side walls (for it is plain that side walls, if in contact with the soil, will absorb water as easily as do the foundations). In the first method an 'area' is made so that the soil does not touch the side wall ; the area is floored with concrete, and a single damp course is all that is necessary, *above the ground and below the room floor.*

In the second method the wall is made hollow up to a point a little above ground level, and at this point a

second damp course is built in, reaching from the outside to the hollow.

By these means ground water is excluded from a building, and it is very important to remember that *the same measures also protect the building from the entrance of ground air,* which, as shown before, may be impure and injurious.

The side walls further up are often soaked by rain, and there is a risk of this soaking through. This can be largely prevented by the use of paint and varnish on the inner side of the walls, or, a more expensive method, by lining the walls with glazed bricks or fine cement. Sufficient protection in ordinary dwelling-houses is, however, provided by good thick walls, and the risk of rain getting through the side walls is not of much importance.

A certain amount of air will also get through the walls, but it may be mentioned here that, from the point of view of ventilation, this passage of air through the walls is not worth consideration ; this air in a dwelling-house will probably do neither harm nor good, so that it does not matter whether the walls are glazed or varnished (which prevents the passage of air) or not. In hospitals, however, where the air contains an unusual number of bacteria, the backward and forward passage of air leaves bacteria in the wall, and these may later be passed again into the building. For this reason, and also because of the extra importance of keeping hospitals dry, the inner surface of the walls must be rendered impervious by glaze or varnish.

It is obvious that windows must be well made and well fitting, or rain will directly enter the rooms—to say nothing of draughts. Another important point about window construction is that the outer sills must project well out from the wall of the house, so that the rain falling from them shall fall clear of the wall below and not soak it.

The roof, however, is the place where there is the chief risk of rain entering the house, and a well-made roof is of the greatest importance. Tiles and slates are the materials generally used, and both are very efficient;

tiles are the more picturesque, while slates are perhaps less easily dislodged and more economical in the long run. The first essential, whether tiles or slates are used, is that the fitting must be perfect, so that no spaces are left through which rain can fall. There must be a proper slope to the roof so that the rain runs off easily, and here again the importance of good fitting is clear, for if there are any cracks about the water will soak through them. Last, but not least, the arrangements for draining the water off the roof must be perfect: the eaves must project over the walls of the house, and the gutters and pipes must be in good order and not leaking. A leaking gutter or a choked pipe are common causes of dampness, since either may result in water soaking continuously along a particular part of the wall of the house.

The *warmth* of a house, so far as its construction goes, depends chiefly upon the thickness of its walls and the good construction of its windows. The air space under the lowest rooms is, however, of great value in keeping the house warm, for air is a bad conductor of heat: even if this space were not of such importance for the exclusion of ground air and water, it would be wanted for purposes of warmth, for the soil in which the house lies is very cold in winter. Similarly there must be an air space between the roof and the ceilings of the rooms underneath, or these rooms will be bitterly cold in wet and wintry weather, and very hot when the summer sun is shining.

Further protection is afforded by the use of double walls and double windows. These are extremely effective and serve a double purpose, for not only do they keep a house warm in winter, but also cool in summer: they are used far more in places such as Canada, where the extremes of weather are very great, than they are in Great Britain.

It may be mentioned here that the fires and other methods of heating houses, which will be described later, serve not only to keep a house warm, but also to keep it dry.

CHAPTER XI

BUILDINGS (*continued*)

So far we have spoken of what we may call the ‘ shell ’ of the house—that is, the actual construction of walls and floors. The three considerations are that the house shall be *stable*, and, as far as possible, *warm* and *dry* : in the attainment of the two latter ends the internal arrangements are also of importance. The internal arrangements must be such that the house is

(*a*) well ventilated,
(*b*) well heated,
(*c*) well lighted,
(*d*) supplied with good water,

and (*e*) properly drained.

Ventilation, which has been partially considered in Chapter III, is the means by which a house is provided with a proper air supply ; this signifies not only that fresh air is provided but that impure air is removed. Since the household is dependent for its pure air upon the air outside the house, it is very clear that this air must be as pure and abundant as possible ; in this lies the importance of the various considerations of back to back houses, courts and small squares, nearness of pig-styes, &c.

The amount of air space and fresh air required for every person in a room has been discussed in Chapter III; it is sufficient to say again that each person requires 3,000 cubit feet of air every hour. Ordinary ventilation is not conducted in such a way that our air supply can be exactly calculated ; experience has shown how the necessary fresh air can be obtained, and it only remains to examine the various ways in which impure air is removed from a room and fresh air brought in to take its place.

Some of the properties of gases (and so of air) make ventilation easy.

If two jars, containing two different gases, are placed with their mouths in contact, the contained gases will mingle with each other until, in course of time, analysis will show that each jar contains an equal mixture of the two gases. This is due to the fact that the minute particles or *molecules* of which the gases are composed are in constant rapid motion; clearly, then, molecules may travel right out of any gas-containing vessel, unless this vessel is completely enclosed. Imagine the two jars just mentioned to be full of minute rapidly travelling particles; when placed mouth to mouth the two jars will form, practically, one single chamber, and it is easily understood that, in course of time, this chamber will contain an equal mixture of the two gases in all its parts.

Now imagine this same experiment on a large scale. Suppose, on the one hand, a room (with the window open) full of impure air, and, on the other hand, the whole atmosphere. Even if it is a perfectly still day, with no breath of air to be felt, the air inside and outside the room will soon be of the same composition; in other words the room will, in course of time, be full of fresh air, for the impurities contained in one room will have no appreciable effect on the vast mass of air outside. This process, by which gases mingle with each other, is known as *diffusion.*

It will be quite clear that diffusion will be hastened if wind is blowing—that is, if the air is being moved about on a large scale. If the wind is blowing towards the room some of the outside air is blown directly in, and, as a result, the room air is forced out in its place. Whatever the direction in which the wind is blowing there are bound to be eddies and currents of air either bringing fresh air in, or sucking room air out. In any case the exchange of air will be greatly quickened.

Now the winds (see p. 64) are *convection* currents set up by the unequal heating of different portions of the atmosphere: we may say, then, that diffusion of gases

allows of interchange between the air in a room, or house, and the air outside, and that convection currents in the air outside hasten this interchange. If at the same time there are convection currents *inside* due to unequal heating of the air of the room, these will also hasten the interchange *provided proper use is made of them.* We shall find that the convection currents caused by the various methods of heating houses are of enormous value in aiding ventilation, and that proper ventilation would be almost impossible without them, in cold weather, unless artificial means of producing air currents were employed. Let us, however, for the present still consider the conditions when rooms and houses are not heated.

So far we have spoken of an empty room; an open window is sufficient to ensure perfect ventilation—that is, to ensure that the composition of the air inside and outside the room will be the same. The open window will act both as *inlet* and *outlet.* Let us now suppose the conditions which are most usual—that ventilation is required for a room which is full of people.

They are all breathing out *warm* impure air, and they are also warming the air actually round them. This air, especially that which has been breathed out, is less dense than the colder air in other parts of the room: it will therefore rise toward the ceiling, and the unheated air will flow in to take its place. Thus the mere presence of people in the room causes definite convection currents, and it must be noted that the impure air, as long as it is warm, tends to collect in the upper part of the room. After it cools it will *sink* again, because the carbon dioxide, which is the chief impurity, is denser than the rest of the air. We see, then, that it will be an advantage if we have a definite *outlet* high up in the room to let the warm impure air escape, and a definite *inlet* lower down to let fresh air enter. That is to say—*windows open top and bottom* provide a more perfect means of ventilation than a single open window; the upper window acts as an outlet, and the lower as an inlet.

Even in summer it is not always comfortable to have windows open in this manner, for violent draughts may be caused, and also rain and dust may enter.

In an ordinary dwelling-house, however, the windows can always be thrown open several times in the day, so that the rooms may have a complete airing, and, provided the intervals are not too long, this is amply sufficient to procure sufficient ventilation ; it is, however, best of all to have a window continuously open.

In schools or other places where rooms are crowded, or in hospitals where fresh air is of special importance, occasional airing, even several times a day, is *not* sufficient to deal with the impurities produced, and it is necessary to make arrangements for an ample *continuous* supply of fresh air, *without draught.* To avoid draught it is desirable to provide inlets which give the incoming air an *upward* direction, so that it shall spread out over the room and afterwards sink gradually ; it will also be slightly warmed.

Similarly a continuous supply of fresh air is needed in bedrooms, for it is plain that one cannot constantly get up during the night to air the room. It is very rare, indeed, for people really to be unable to keep a window open in their bedrooms, and everybody should accustom him or herself to this : plenty of fresh air while we sleep is a great help to good health.

To meet the cases where continuous supplies of fresh air are needed, and yet windows cannot be left open, there are many contrivances : some of these are modifications of ordinary windows, and others open directly through the wall.

Window contrivances. The most valuable arrangement is to have a good-sized pane (or panes) which is hinged along its lower border so that when opened (usually by ropes) it falls inwards towards the room. By this means a large inlet is provided and the incoming air is directed upwards. It must be noted that in an unheated room the apertures so produced must act as outlets as well as inlets.

Wall contrivances. The *Sheringham* valve acts on the same principle as the hinged window-pane. It is simply a metal box fitted into the whole thickness of the wall : the outside is open to the outer air (though protected with a grating), and the inner side is closed by a metal flap hinged along its lower border. This can be opened

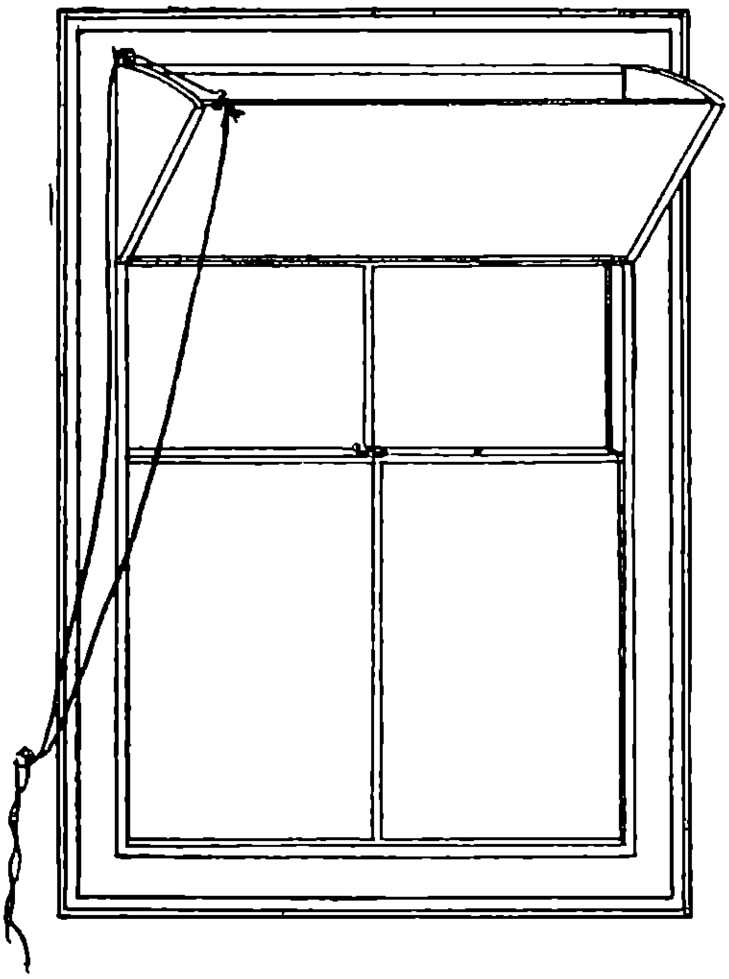

Fig. 34. Hinged window-pane.

towards the inside of the room so that air is allowed free entrance, but is directed upwards.

The *Tobin* tube is explained by the diagram, Fig. 35; the top can be closed or opened, as desired.

Ellison's bricks are perforated with cone-shaped holes, the narrow opening being at the outside. This air is not directed upwards, but draught is prevented by the incoming stream being spread out fanwise and thus having its velocity reduced.

One or two points must be noted about these artificial inlets. (1) They are more effective, as will be clear later,

in heated than in unheated buildings, for in the former the outlet for the products of combustion resulting from the heating apparatus can also be used to make a very efficient outlet for impure air. (2) There must be plenty of them: one Sheringham valve is of little use for a classroom full of children. (3) They are unnecessary in ordinary dwelling-houses, though there is no objection to their use in these, for they are comfortable and

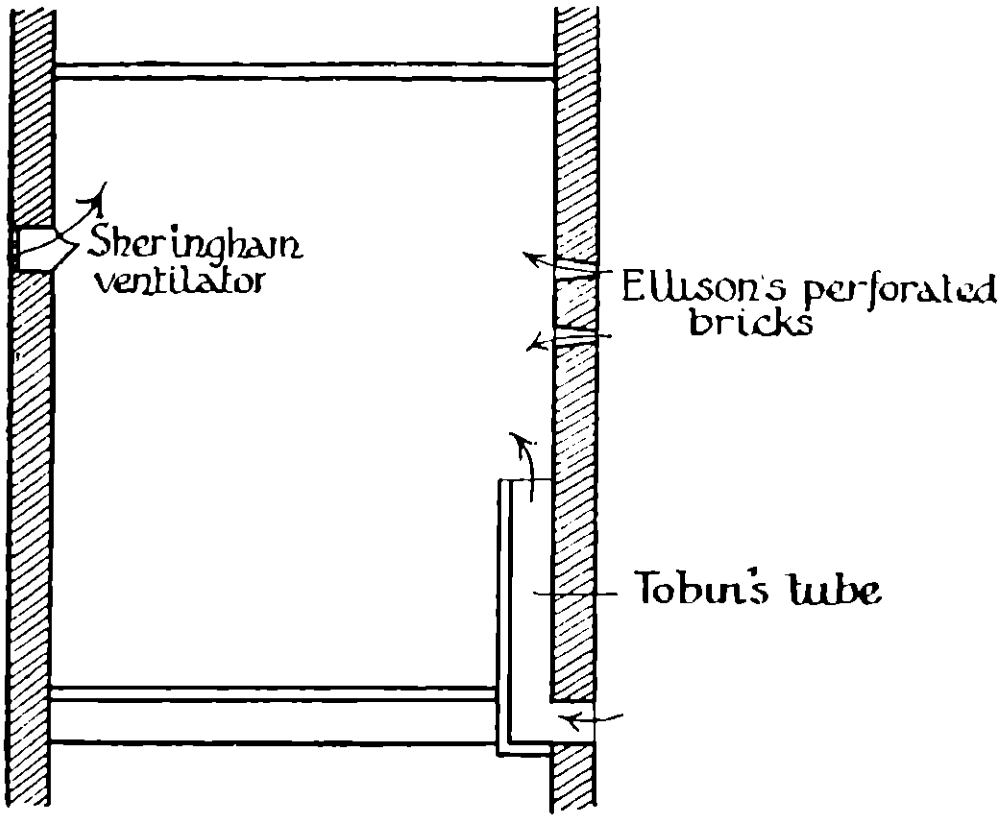

FIG. 35. Ventilators in walls.

efficient. For those who can afford them, double windows are very comfortable ventilators for dwelling-houses. The lower pane of the outer window and the upper pane of the inner window can each be half opened, so that a sufficient volume of upward-flowing air is brought into the room.

Ventilation of heated buildings. The question of ventilation is more urgent in winter than in summer, because the air indoors is more likely to be impure. In the first place people are indoors a good deal more, and in the second the fires and lights which are in use are likely to add to the

impurities of the air ; at the same time the air outside is so cold that it is not easy to let it in freely.

Fortunately, however, the various methods of heating all lend themselves to the aid of ventilation. Let us therefore discuss these various methods and consider both their efficacy as heating agents, and their use in ventilation at the same time

The chief methods of heating are (1) open fires, (2) closed stoves, (3) hot air, and (4) hot-water pipes.

Open fires are commonly used in Great Britain. The old-fashioned fireplace was so extremely wasteful that great attention was paid by inventors to other more economical forms of heating. Competition, however, as usual, led to improvement, and the modern fireplace is so much better than its predecessors that it seems very unlikely that the open fire will disappear from the average English home: it is already, however, disappearing from large halls, schools, and other public institutions. In the old grate it was calculated that seven-eighths of the heat produced was lost up the chimney, but in the best types of modern grates the waste is far less. Coal, coke, and wood are burnt on open fires, and open gas-stoves are also commonly used : for the present let us speak of the ordinary coal fire.

An open fire heats a room almost entirely by *radiation.* The radiant heat from the fireplace strikes upon and warms the various objects which are exposed to the fire. These objects in turn heat the air in their neighbourhood and produce small convection currents which gradually warm the air of the room, but the air is not directly heated by the fire itself, except that air which is in its immediate neighbourhood—and most of this goes up the chimney. An open fire, therefore, does not produce equable heating of the air in a room, but actually heats the various objects (including persons) in the path of the radiant heat.

It follows, then, that one must be near the fire to be warmed, if the fire is of moderate size, and also that one

must be directly exposed to the rays : a screen stops the greater part of the heating effect of an open fire. Conversely, if the fire is hot enough to heat the more distant parts of a room, it will be uncomfortable to go anywhere near it.

This fact—that an open fire does not heat a room equably—is undoubtedly a disadvantage ; the second big disadvantage is that it is rather extravagant, even with a modern grate. Other objections are that it causes a good deal of trouble in laying and lighting, clearing out, cleaning the grate, &c. ; that it produces a certain amount of dirt and dust ; and that if the chimney is 'smoking' it may be an intolerable nuisance instead of a pleasure.

This seems rather a formidable list of disadvantages. What then are the good points of an open fire, which make English people so slow to take to other forms of heating ? In the first place an open fire has a very cheerful appearance—much more so than a stove, or any amount of hot-water pipes, and in the second place there is no doubt that, to those who are accustomed to it, radiant heat is much the most pleasant form of heat. An English family derives much more pleasure from sitting round an open fire than from sitting in any other well heated room. These two facts alone are quite enough to make the average Englishman say that he doesn't mind how his halls and churches and factories and childrens' schools are heated, but that he wants a fireplace to sit in front of when he is in his own home. Fortunately hygiene is able to support him by giving another great argument in favour of open fires ; this is that they are most excellent aids to ventilation. It was said above that all methods of heating lend themselves to the aid of ventilation, but one can go further than this when speaking of open fires, and say that they actually *cause* ventilation by the mere fact that they are burning ; the way in which they do this will be discussed very soon ; in the meanwhile it is sufficient to state the fact.

Let us now consider the various forms of modern grates.

The first really marked improvements over the old-fashioned grates were contained in that devised by Teale, and a Teale's grate is not easily beaten yet. The following are the special points of this grate as compared with its predecessors.

(1) Metal is replaced as much as possible by fireclay. The back and sides are composed entirely of fireclay, which absorbs heat and then radiates it into the room instead of passing it back into the walls.

(2) The back slopes forwards and upwards towards the room, and the sides incline towards each other; much of the heat of the fire is, therefore, taken by the fireclay instead of passing straight up the chimney. At the same time the inclination of the back, by narrowing the 'throat' of the chimney, improves the draught and lessens smoking, and also projects heat towards the floor in front of the fire, where heat is wanted as much as up above.

(3) The fireplace is built low down for the same reason, and well into the room.

(4) The front bars are narrow and vertical, with narrow intervals. The bars thus intercept less heat, and allow fewer coals to drop out.

(5) The under bars are likewise narrow, and set close together, so that coal does not fall through till it is burnt to ash.

(6) The space underneath the fire can be closed in front with an 'economizer', so that once the fire is lighted and burning properly the draught of cold air underneath can be diminished: the fire can therefore burn more slowly and less wastefully.

The net result of these improvements is that the same quantity of coal will give out a far greater amount of heat: the fire lights more easily and smokes less: also it can be kept just burning when the room is unoccupied and quickly revived when wanted.

It may further be mentioned that much time and labour are saved by having the hearth and sides of the grate tiled, and so doing away with constant 'black-leading'.

These principles are, in the main, carried out in all modern grates; but there are several modifications in other patterns.

Many grates are 'barless' in front, the fire lying in a small 'well'; it is claimed that more heat is given out,

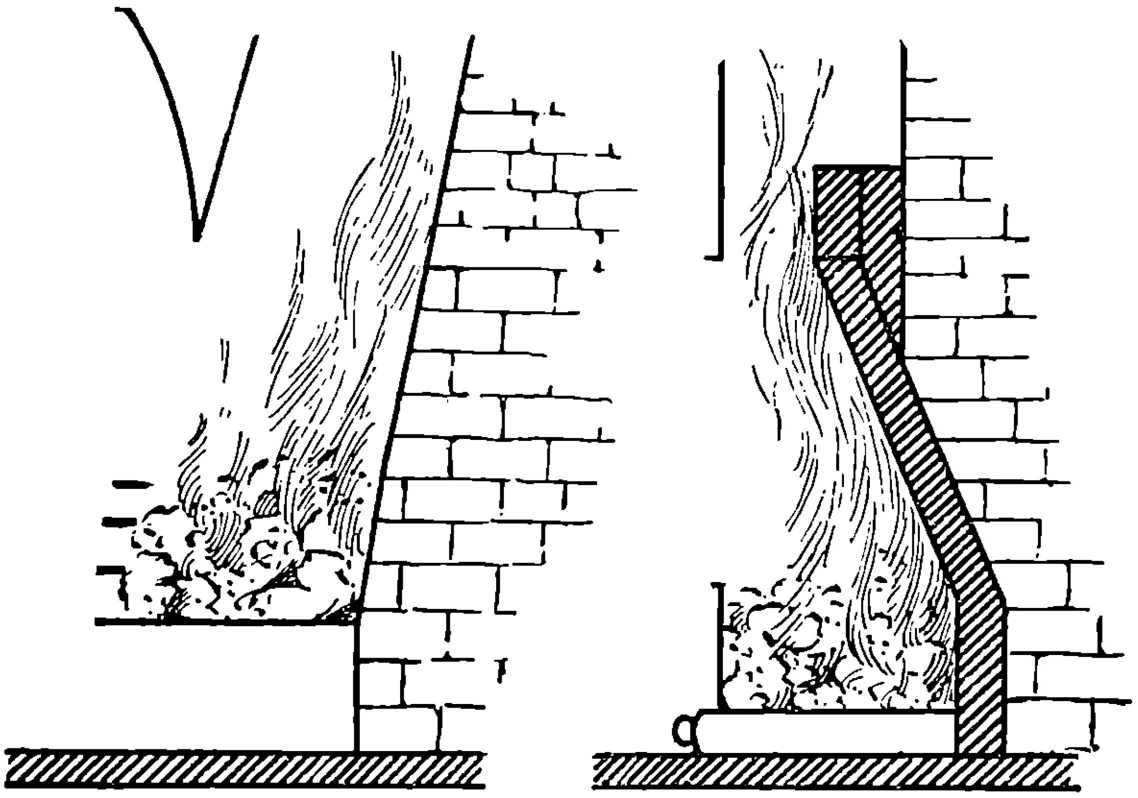

FIG. 36. Diagrams of old and Teale grates.

owing to the radiation being uninterrupted. In the 'Eagle' hearth grate, which is of the 'barless' type, the bottom bars are made of thick fireclay, and there is a great deal of fireclay in the grate altogether; the combustion is very complete, and the heat very well radiated; there is, however, rather more chance of breaking fireclay bars than there is of breaking an iron grating. In the 'Devon' grate there are no bars either in front or below, and the clay bottom is laid right on the hearth: there is thus no draught underneath the coal at all, and these grates are extremely economical and the combustion

is very slow and complete; naturally, however, the fire is rather more difficult to light, or to revive when it has burned very low. In many grates there are adjustable 'canopies', which when closed increase the draught through the fire and so increase the rate of combustion, and when opened allow more draught to pass *over* the fire and so reduce the rate of combustion. In the 'Peveril' grate this principle is improved upon, so that when opened there is only just sufficient draught to keep the fire

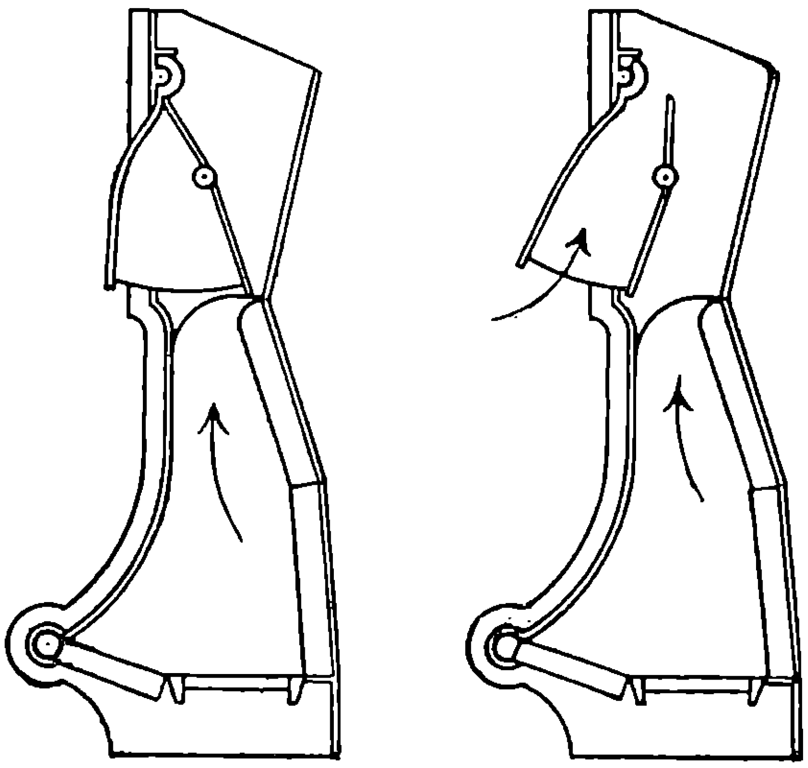

FIG. 37. Peveril canopy.

burning, and combustion is reduced to a minimum: the 'Peveril' also stands well out over the hearth and is a powerful heater.

In all modern grates, and especially in those on the lines of the 'Devon', the heat of the hearth is intense; to avoid risk of fire, no woodwork must be allowed in floor or walls in the near neighbourhood of the fire.

Fireplaces should not be placed in the outer walls of a house, for heat is thereby wasted; the same applies to the flues, and the ideal arrangement is to have all the flues concentrated towards the centre of the house. It is

better not to allow the flues from separate fires to communicate with each other, but this sometimes cannot be helped.

The flues should not be too wide, especially in their upper parts, or the draught will not be effective: and the chimney-pots must stand well above the roof. Smoking is commonly caused by wind blowing over parapets, or over adjoining houses and sweeping down on to the chimney-pots. There are many types of apparatus fitted on to chimneys to prevent smoking, but they mostly work on one or other of the following principles: (1) a cowl, or hood, is fitted which revolves with the wind in such a way that its back is always turned to it, or (2) an apparatus is fitted which is so designed that it also revolves with the wind, and when it revolves causes a definite draught *up* the chimney.

Open fires as ventilators. A fire is of such great value as a ventilator because it provides what we may call a 'positive' outlet. The air that passes through the fire is heated, and consequently becomes less dense and tends to rise; as a result, a constant current of air passes through the fire, up the chimney, and so out of the house altogether the same is true, though to a rather less degree, of the air in the neighbourhood of the fire, and altogether there is a considerable volume of air passing out of the house by way of the chimney. By the same route the various impurities produced by the combustion—chiefly carbon dioxide—are safely removed without entering the room in which the fire is burning. We may put these facts, and their results, in a logical form as follows:

(1) When a fire is burning in a room a considerable volume of air is leaving the room.

(2) When air is leaving a room, air must be entering to take its place.

Therefore (3) when a fire is burning in a room, air must be entering the room.

It only remains, then, when a bright fire is burning in

a room to see that the air which enters is derived from a pure source, and that it enters without causing discomfort to the inhabitants. When windows and doors are shut the air enters through the various cracks and crannies in the joints of these: that coming through the windows is reasonably certain to be pure, while that coming by the door is not so certain, for it is only air from other parts of the house. It is necessary, therefore, to encourage entrance by the windows and discourage entrance by the door, and the simplest and best way of doing this is to open the top of a window: it is better to open it a reasonable distance than only to leave a narrow crack, both because there is freer entrance for air and also because it will really cause less draught, since the air will enter with less velocity. Failing an open window any of the contrivances such as hinged panes, Sheringham valves, &c., will form good inlets. It is well to close up the crack between the bottom of the door and the floor, because the air coming through this is not necessarily pure, and also leads to a cold draught along the floor.

We come back to our former statement—that in an ordinary dwelling-house an open window is the best inlet for ventilation.

There are various devices by which the fire not only produces an incoming current of fresh air, but warms it as it enters, so that the room is supplied with fresh warm air. In Galton's grate—devised by Sir Douglas Galton—the chimney-flue passes through an air-chamber at the back of the grate. This air-chamber is connected on the one hand with the outer air, and on the other opens into the room by an opening high up above the mantelpiece. The result is that this connexion with the outer air forms the easiest means of inlet, and that the bulk of the incoming air comes by this way. In its passage through the air-chamber it is warmed by contact with the flue, and so enters the room in a warm condition. When it has cooled a little it will sink and spread through the room, and in its turn will be carried away to the outside air by the

chimney. Note that this arrangement—which is very good—generally means a fireplace on an outside wall, but obviously it saves heat instead of losing it.

It is worth remembering that a canopy which will, when fully open, practically close the chimney, only

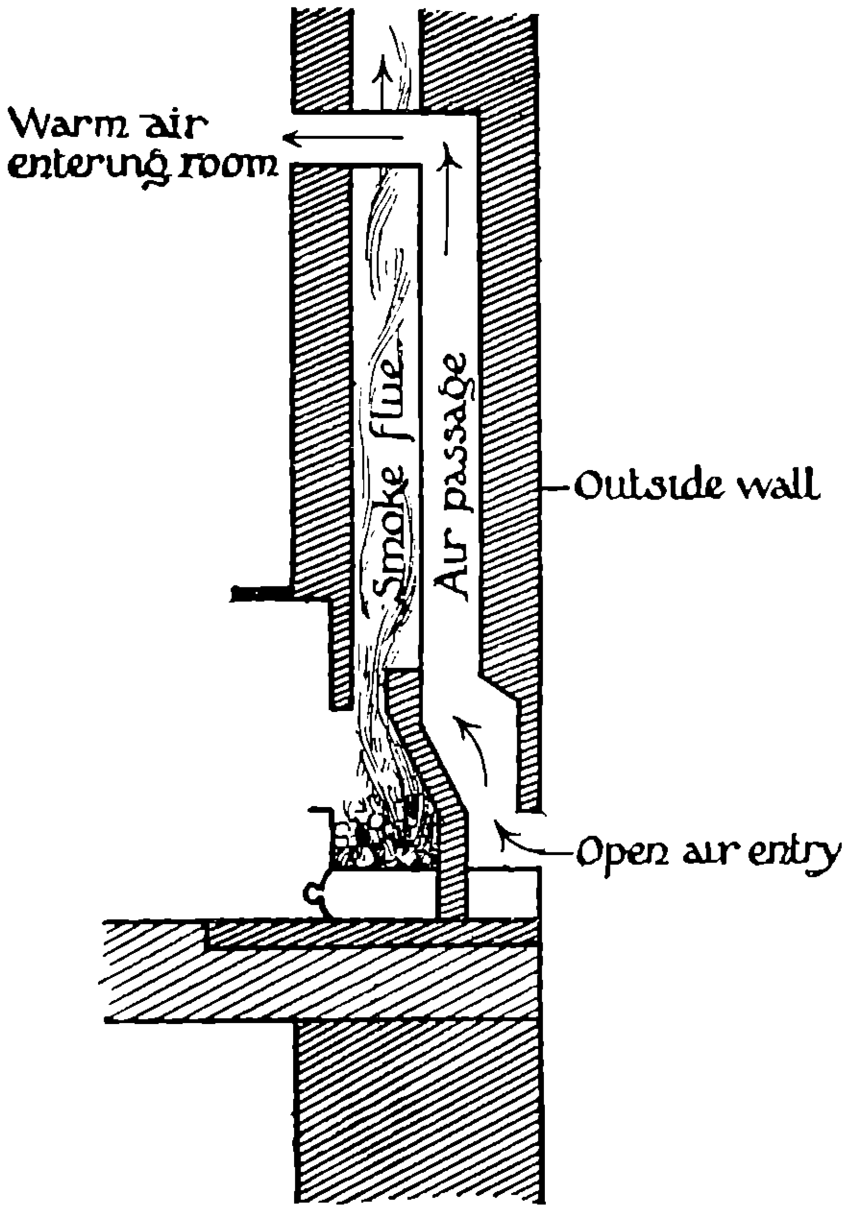

FIG. 38. Galton's grate.

allows just sufficient air to pass to keep the fire burning. Under such conditions the fire is less effective as a ventilating agent.

Wood can be burnt on open fires, but much more of the heat is wasted, and it is difficult to keep a fire burning all day without the help of some coal. Coke is often put on open fires after they are well alight to lessen combustion,

and so reduce expense: coke makes a dull fire, and is more difficult to keep alight.

Open gas fires have the great advantage of giving exceedingly little trouble: they are often very useful in invalid's rooms as they need no clearing out or laying, and save the occasional noise due to poking, or to falling coals. There is really very little to be said against open gas fires anywhere, except that people do not like them so much as coal fires. It is highly important, however, that they should be fitted to a good flue as the products of combustion are highly poisonous.

Closed stoves work on a different principle. A stove is practically a metal case, generally cylindrical in shape, in which material can be slowly burnt; just sufficient air enters at the bottom to supply the necessary oxygen, and the products of combustion escape by a flue passing upwards to the outer air. The joints of the stove and flue must be well made and air-tight, or the poisonous combustion products escape into the room. The fact that all the draught, which can be well regulated, passes through the burning material accounts for the fact that, in a good stove, almost anything that *can* burn will burn: coke is the material most commonly used, but many specially constructed stoves now burn anthracite coal. Stoves—and especially anthracite stoves—give little trouble and are economical.

A stove heats the room or building in which it is placed *chiefly* by convection. The air round the stove—and also round the flue—gets strongly heated and rises towards the ceiling; other air takes its place, and so convection currents on a large scale are set up and the *air* of the whole room is gradually warmed: there is also a certain comparatively small amount of radiation from the hot sides of the stove.

One may say, in short, that the air which is *directly* heated by a stove remains in the room, but that most of the air which is directly heated by an open fire goes up the chimney.

A room is more equably heated by a stove than by an open fire—it is not very hot near the stove, and perhaps very cold in other parts of a room—and this, together with the small trouble and the economy, constitute the three great advantages of a stove compared with an open fire.

The disadvantages are as follows. It is not so cheerful in appearance as an open fire, and it is not so pleasant to be warmed by hot air as by radiant heat.

The air may be made unpleasantly *dry* ; this, however, can be remedied very largely by the simple means of putting a bowl of water on the stove, the evaporation from which tends to make up for the dryness caused by the heating of the air.

A more serious objection is that there is a risk of *poisonous products of combustion* getting into the room. This happens particularly when the stove is made of cast iron (which is commonly used), and when portions of the cast iron become red-hot. Red-hot cast iron allows *carbon dioxide* to pass through from the stove to the room air ; at the same time some of the carbon dioxide in its passage through the red-hot iron is converted into another gas known as *carbon monoxide*, and this gas is an active poison.[1]

This danger of the passage of gases is almost entirely removed by the use of wrought iron, and also by lining the stove with fire-brick, and by fitting it with tiles on the outer side. At the same time fire-brick and tiles rather reduce the heating powers of the stove, for these depend a good deal on the ease with which heat is conducted through the stove walls.

If a stove becomes very hot, there is apt to be an unpleasant *burnt smell* ; the cause of this is not quite certain, but it is possibly due to the charring, against

[1] Carbon monoxide, like carbon dioxide, is a compound of carbon and oxygen, but contains only half as much oxygen. Its acute poisonous action is due to the fact that the haemoglobin in the blood takes it up even more readily than it takes oxygen : carbon monoxide literally 'turns out' the oxygen from the red blood-corpuscles, and death results from lack of oxygen.

the sides of the stove, of the minute organic particles present in the air.

Lastly, there is the important fact that a stove is not such a good natural ventilator as an open fire; by this is meant that the mere fact that there is a stove burning in the room does not ensure a good current of air entering a room, for the draught through the stove is only sufficient to keep it alight. If the stove is kept burning very fiercely, there will be plenty of draught, but then all the advantages of economy, &c., are lost.

However, though a stove is not a good natural ventilator, it can easily be made to lend itself to ventilation. The simplest thing to do is to take the flue up an open chimney; the hot flue will then heat the air in the chimney and cause a constant outward current of air along this in exactly the same way as does an open fire, though it will not be quite so effective.

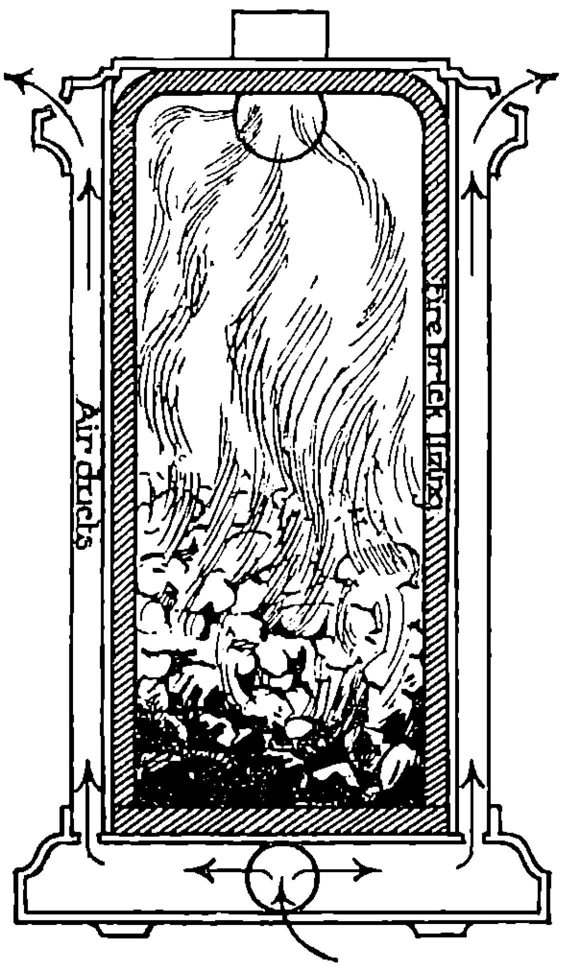

FIG. 39. Ventilated 'tortoise' stove.

Besides this there are many devices for making the stove itself draw in a current of fresh air from the outside, and pass it into the room, having warmed it on the way. The diagram shows a very simple application of this method in the 'tortoise' stove.

So far we have spoken of stoves which burn *coal* and *coke*; there are also many stoves devised to burn *gas* on the closed combustion principle: many of these are very efficient and economical.

Heating by hot air. In this method the fresh incoming air is heated before it actually enters the room or building

to be warmed. It should be noted that this principle is often used in combination with other forms of heating; Galton's grate, and the various ventilating stoves, both supply warm air in addition to the heat they themselves supply to the room: it will be seen that hot air can also be used in combination with hot-water heating. Hot air is really used to some extent when a stove is used in the central hall of a house, for the currents of warm air tend to rise and spread through the various passages and lobbies above and also to get into the rooms opening off these.

There are, however, more elaborate methods of supplying constant currents of warm fresh air to buildings; these are generally used in large buildings, in which they are perhaps the best methods possible of combining heating and ventilation. The following is a simple description of the type of method in use: the air is drawn into the building, filtered on its way, and then passed over a furnace; it is afterwards allowed to pick up some moisture and then conducted through the building, entering the various chambers by means of gratings in the floors. It is then drawn on towards a definite outlet; this outlet is, perhaps, the most important part of the whole arrangement, for it is really the outlet that is the positively working part. There may either be a second furnace burning at the foot of a long and big flue, or there may be big fans revolving so as to cause a constant current. In either case it is the current produced at the commencement of the outlet that draws the outside air into the building and over the first furnace, the flue of which is unconnected with the incoming air supply.

Sometimes for economy's sake the air is not allowed to leave the building altogether at the place we have spoken of as the outlet, but is brought round again to supply the draught for the first furnace. In this case both furnaces have a draught of heated air, and so burn considerably less coal, and it is also clear that both furnaces help in producing the current of incoming air. Remember that the air goes *over* the first furnace, *through*

the second furnace (or fans), and then may either leave the building at once or first be brought *through* the first furnace.

Heating by hot water depends on the fact that hot water is less dense than cold, and therefore tends to rise to the upper part of any enclosed system of water pipes ; the convection currents produced by heating water are, in fact, made use of.

The diagram shows the main principles of a very simple arrangement of the usual system employed—the low-pressure system such an arrangement as may be found, for instance, in a small greenhouse.

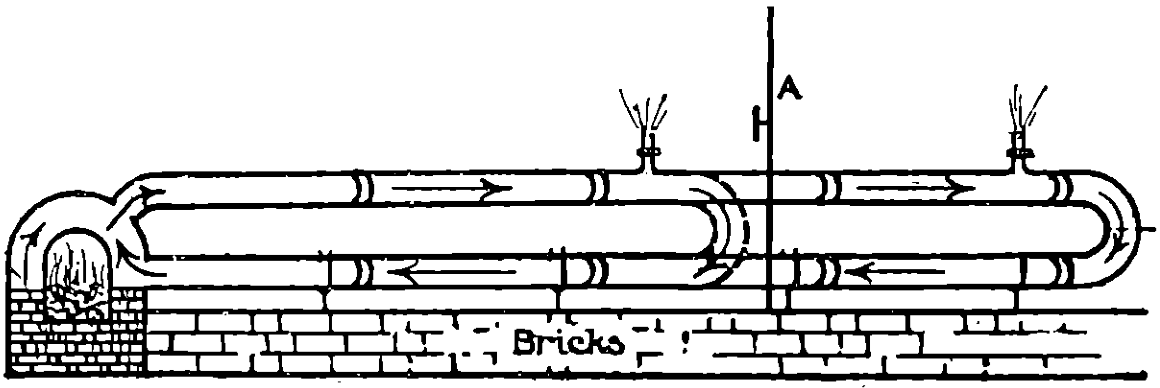

Fig. 40. Hot-water heating.

It consists, in the main, of a *boiler*, which can be heated by a stove or small furnace, and a closed system of pipes ; the *outflow pipe* leaves the top of the boiler, is carried along as much of the building as is desired, and eventually returns as an *inflow pipe* which enters the boiler at its lowest part. The whole system is kept nearly full of water, and as soon as the boiler is heated circulation of water begins. The hottest water at once rises to the top of the boiler and begins to pass out by the outflow pipe, and cold water enters in its place by the inflow pipe. In course of time the whole system gets hot and all the pipes contain hot water, but the hottest water is always that at the top of the boiler and the commencement of the outflow pipe. Safety-vents for air and steam are provided at places along the highest part of the system, and there must also be places for occasional refilling with water.

The hot water in the pipes will naturally set up convection currents in the air in their neighbourhood, and thus the air will be gradually warmed. There will also be some radiation from the hot pipes, but the greater part of the heat produced is due to convection.

Let us now consider how this very simple system can be elaborated. This is easily done, for the pipes can be carried in any direction or manner desired ; they may be taken in a single or double row right round the greenhouse, or can be coiled so as to make four rows, or special extra coils can be made at any place where extra heat is required. Suppose, again, that at the point A the greenhouse is divided into two parts, and that the part farthest from the boiler does not always need heating ; valves can be fitted at this point so that the part beyond can at any time be entirely shut off from the rest of the system, and by this means the heat can be economized.

These principles can be carried out through any sort of building, whether a dwelling-house or a public institution. The point to remember is that the outflow pipe must at once be carried to the highest part of the system, and can then be conducted round the building till it again reaches the boiler at its lowest part as the inflow pipe. At any place where extra heat may be required the pipes can be coiled in several layers, and rooms, or whole wings of a building, can be shut off from the hot system, whenever required, by means of valves.

It is readily seen that this system entails little trouble, and keeps hot as long as the one furnace is maintained. It is estimated that, when used for a building, about 12 feet of four-inch iron pipe should be allowed for every 1,000 cubic feet of air to be warmed. In this low-pressure system the water does not reach the boiling-point.

It is also easy to combine hot-water heating with heating of incoming air, and there are two common methods of doing this.

(*a*) A coil of hot pipes is enclosed in a casing beside the wall of a room ; in the wall is an inlet for fresh air, and the

top of the casing is perforated so that the fresh incoming air is heated and passed into the room in a warm stream through the grating.

(*b*) In large buildings, such as churches, the pipes are carried under the floor, and over the pipes are gratings ; air is drawn in over the pipes and passed through the gratings into the buildings.

Artificial ventilation. So far we have spoken almost entirely of natural ventilation, and the ways in which the ordinary methods of heating buildings can be used to ensure good currents of air ; it will have been noticed that the heating apparatus generally causes a positive outlet, and that all that is necessary is to provide apertures in connexion with the outside air ; these apertures will act as inlets. The description of heating by hot air, however, gave instances of artificial ventilation (see p. 214); in this example, either revolving fans or a furnace (which was not used for heating the building) were used to produce a constant draught of air. Artificial ventilation, then, simply means that mechanical means are used directly to draw air out of a building, or directly to drive it in ; or the two may be combined. In the first case proper inlets, and, in the second, proper outlets, must be provided. Artificial ventilation is of great value in large buildings, and in schools, where any means of natural ventilation may be unable to provide a sufficient supply of air.

Ventilation of halls and passages. It is just as necessary to ensure good ventilation of these parts of a house as it is of the living-rooms. Not only must they be clean and sweet for their own sake, but one must remember the important fact that however much care one takes to ensure air entering the living-rooms from outside, a great deal will also come in from the halls and passages, and this air must be as pure as possible. Fortunately this entrance of air into living-rooms cuts both ways, and goes some way to ensuring ventilation of the halls and passages themselves ; there must also, however, be plenty of open windows in the upper passages.

Remember, again, that the fires and stoves which are used for warming houses are not only used for this: they are of great value as ventilators, and, besides this, have a valuable *drying* effect.

Lighting of buildings. Good light is of the greatest importance both to comfort and health. The three chief forms of artificial light are provided by (1) electric light, (2) coal gas, and (3) oil.

Of these three *electric light* is, on the whole, the best. It is the most convenient, the cleanest, and the healthiest; the most convenient because it is turned on by merely pressing a switch which can be placed at any distance from the lamp, and the cleanest and healthiest because there are practically no products of combustion, and, also, the heat produced is not great. The risks of fire are very slight provided that the connexions are not meddled with by people who know little about electric currents. Even the simple operation of 'mending a fuse' should not be done by inexpert people, for the 'fuses' are the great safeguards against fire, and different kinds of wire are needed at different places. The 'metallic filament' lamps are much more economical than the carbon filaments.

The light, if very strong, may be trying to the eyes, but this can always be got over by using ground glass globes, or by careful shading; there is no reason to believe that electric light is more trying than any other light of equal strength.

In speaking of *coal gas* let us consider only the 'incandescent' burners, for these are vastly superior to the old 'fish-tails'

Gas has one important advantage over electric light—namely, that it is more economical. In lighting power the two may be considered equal, but in other respects gas falls short of its rival. Even the best incandescent burner is bound to produce more dirt and heat, and to add more impurities to the air than an electric lamp of equal power.

It must be remembered that when gas is laid on in

a house it may also be used for heating and cooking purposes. So, indeed, may the electric current, but the cost is, at present, rather great ; the cost should, however, gradually become less.

Oil lamps come in a bad third in all houses where time and money are of very great importance—that is to say, nearly always. Their only recommendation is that they give a very soft pleasant light, and some people prefer still to use them, even when the other forms of light are available ; obviously they must still be used very largely in the country where no electric current or gas can be obtained.

They give a great deal of trouble, they are expensive, and they produce much more heat, dirt, and impurities than does incandescent gas.

Since gas and oil add appreciably to the impurities in the air, it is clear that when they are used, special pains must be taken with ventilation.

So much for artificial light : the natural light in the daytime also needs some consideration. Plenty of light is of great importance to health, and we have already emphasized the fact that houses should have a full supply of windows, and as much sunlight as possible. At the same time good light is needed for the eyes, and it is great folly to read or write or work in a poor light. When writing it is best to have the light from the window falling over the *left* shoulder, so that no shadows are thrown over the paper ; this must always be remembered, in particular, in schools. It is also well to remember that an invalid in bed wants the light behind him to read or write without straining his eyes.

Domestic water supply. (*a*) **Cold water.** Let us first consider houses which rely on natural sources of water. The simplest method is to get one's water in buckets as one needs it, but this entails a great deal of trouble.

An advance is to have a *cistern* which will easily contain enough water for twenty-four hours, and which can be pumped full every day ; the cistern is in connexion

with a system of pipes containing taps at any places where they are needed, and obviously the cistern must be above the level of any of the taps. Water-closets must have separate cisterns which have *no direct connexion* with the rest of the water supply.

The cistern itself is an object of great importance, and much care must be devoted to its construction and management. It is best made of galvanized iron, or of slate slabs set in cement ; lead is also used, but should be well lined with protective material to prevent the water dissolving any lead. An overflow pipe must be provided so that the cistern cannot become overfull, and this pipe must discharge freely into the open air so that no poisonous gases may pass through it into the water. The cistern further needs a well-fitting cover so that nothing can fall in, and it must be so placed that it can easily and frequently be inspected and cleaned.

The water is used both for drinking and household purposes, and, whenever a cistern is used it is really wise to filter the water before it is drunk.

In houses which are supplied from the mains on the *intermittent* system (see p. 96), cisterns are also necessary, and they also must contain a twenty-four hours' supply. All the precautions mentioned above must be taken in these cisterns, for they are exposed to just the same risks of contamination. The other disadvantages of an intermittent system have already been described. Drinking-water in these houses should be filtered.

When the *constant* system is in use, cisterns for the cold-water supply are unnecessary, except for the water-closets, and the cisterns for these must be quite apart from the rest of the water supply. The water from the taps may be reckoned pure, but the precaution must always be taken of running off all water which has been standing in the pipes (if these are made of lead) before drinking it (see p. 99).

(*b*) **Hot water.** A good supply of hot water is so great a convenience and so valuable an aid to cleanliness and,

therefore, to health, that nearly all modern houses are fitted with a hot-water system. The principle used is similar to that used in hot-water heating, but there is further needed some apparatus to ensure that when hot water is run off fresh supplies of cold water enter to take its place, and so there is no risk of the system being emptied : at the same time the cold water needs to be added in such a manner as to make the loss of temperature as small as possible.

There are many systems in use ; the following is a short description of one of the most simple :

The boiler is placed at a low level, usually at the back of the kitchen-range, and from the top of the boiler the *supply pipe* runs up to a hot-water tank placed above the level of the highest hot-water tap. This pipe opens into the upper part of the tank, and from it the various pipes are conducted to the taps. From the bottom of the tank the *return* pipe leads back to the bottom of the boiler.

Note that the taps which are connected with the supply pipe obtain their water from the upper part of the tank, and in this part of the tank the water is hottest.

To prevent emptying of the system a cistern is needed, which is placed above the tank, and which communicates with its lower part. When hot water is run off from the tank fresh water enters from the cistern, and since it enters at the lowest part it mixes but little with the water above, and thus plenty of hot water can be drawn off. If the cistern is placed close to the tank, its water is slightly warmed as a result of its proximity to the hot tank.

The kitchen-range is always fitted with ‘ dampers ’ by which different flues can be closed or opened. One of these flues is in connexion with the boiler, the others with the ovens ; if the ovens are not needed, and the oven dampers closed, all the available heat is used for the hot water, and once this is properly hot, no great supplies of fresh heat are needed ; in other words, the boiler damper can be closed for the greater part of the day, and so coal can be economized.

CHAPTER XII

DRAINAGE AND REMOVAL OF REFUSE

It remains now to discuss the removal of waste matter from buildings, and the disposal of the matter removed.

Waste matter may be divided into

(1) *Liquid waste*: water from baths, lavatories, sinks, &c.

(2) *Solid refuse*: ashes, remains of food, &c.

(3) *Excreta.*

The latter may be removed, according to the type of closet used, with either the liquid or the solid refuse.

Let us first consider the arrangements in a modern town, where houses are supplied with water-closets, and excreta are removed by 'water-carriage', together with the usual liquid refuse.

Drains convey material from single houses, and the owner of the house is responsible for their being kept in proper condition: *sewers* take the joint material from two or more houses, and are under the control of the public authorities.

A perfect drainage system attains two particular ends: firstly, the refuse is carried away from the house as rapidly and easily as possible, and secondly, no *air* is allowed to pass from the drains into the house. It must always be remembered that drains contain air, and that this air, from its contact with the material carried by the drains, is impure: hence the importance of preventing its entrance into buildings.

Let us first tabulate the essentials of a good drainage system, and afterwards consider what the terms employed mean, and how the results aimed at are attained.

A drainage system must be
(*a*) well constructed;
(*b*) provided with a proper 'fall';
(*c*) properly trapped and disconnected;
(*d*) properly ventilated.

(*a*) and (*b*) deal particularly with the first object of a drainage system—that the refuse shall be carried away as rapidly and easily as possible—and they can readily be understood.

Construction. Drains must first of all be absolutely water-tight; they can be made either of well-glazed stoneware, with cemented joints, or of iron lined with rust-proofing material and jointed with lead. If possible they should not be carried under houses, and if they are, they should be embedded in a thick layer of concrete. A diameter of 4 inches is sufficient for ordinary houses, but large buildings require larger pipes.

The drain should run in as straight a line as possible, and any curves that are necessary must be very gradual. Similarly, where branch drains join the main drain the junction must be at an acute angle in the direction of the flow, and not at a right angle. Sharp curves and right-angled junctions tend to cause obstruction, and so to stop a rapid flow.

Fall. The drain must run steadily downhill a fall of 1 in 40 is sufficient for a 4-inch pipe, and a larger pipe needs a more gradual fall. The gradient should be steady all the way, except that it should be made a little steeper when there are curves and junctions.

Trapping, disconnexion, and *ventilation* will be best understood by considering the various means taken to remove the various classes of liquid refuse, and studying the various devices as they come: all these aim at preventing drain air from entering buildings.

Waste water from baths, sinks, &c. This water is carried out of the house as soon as possible by waste pipes, *and these pipes are not continuous with the drain.* As a rule, the pipes discharge over a *gully*, the nature of which is seen

in the diagram, and will shortly be described. Frequently the waste pipes simply pour over the grating, but it is better that they should either open under the grating but *over* the water in the gully, or, as in the diagram, pour on to a short channel which leads to the gully.

In any case the water passes through the air before reaching the gully, and **disconnexion** is attained; any gas that may pass from the drain through the gully

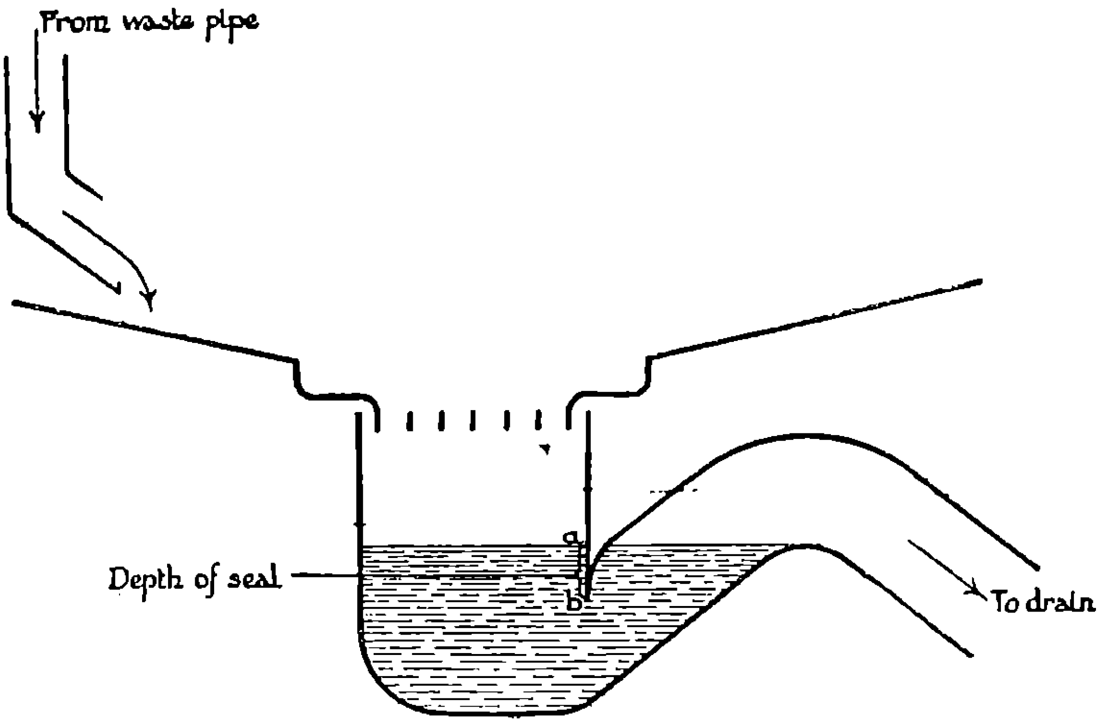

FIG. 41. Yard gully.

will diffuse into the open air instead of passing through the waste pipes into the house.

At the same time, however, provision is made to prevent, as far as possible, any air getting out of the drain at this point at all; the gully is sealed by a **trap**.

Now a trap is, simply speaking, a bend in a pipe which always retains some water, so that gases cannot pass right along the pipe without forcing their way through the water.

There are, however, good traps and bad traps, and it is necessary to understand what makes a trap efficient. The most important matter is the difference in level between the surface of the water in the trap, and the lowest point

reached by the upper wall of the pipe. In the diagram of the gully this difference in level is indicated by A–B, and in the S trap figured on p. 226 by X–Y. This difference in level practically represents the depth of water which gas would have to force away to get through, and may be called the *depth of the seal*: it should be not less than $1\frac{1}{2}$ inches.

The efficiency of a trap does not, however, depend *only* on the depth of the seal. Though the trap must always contain water it must not always contain the *same* water, for this water will gradually absorb gas and give it off again the other side. The trap must therefore be so constructed that fresh discharges from the pipes above carry away the water already in the trap.

The gully trap figured in the diagram answers these requirements; fresh discharges from the waste pipes will leave fresh water in the trap, and the depth of seal is sufficient. There are, however, two other points to be noticed about the gully; firstly, that grease tends to collect in the lower part of the trap and must be cleared away from time to time, and, secondly, that the grating must always be kept clear of dirt, leaves, &c.; if a waste pipe discharges *over* a blocked grating the discharge may fail to get through at all, and if *under* a blocked grating the waste pipe is no longer disconnected from the drain.

It will be clear that proper disconnexion and a good trap make the entrance of drain air through a waste pipe unlikely. The risk is made still less if the waste pipe itself is trapped, as all waste pipes should be. The trap is really not so much meant to stop the entrance of drain air, as to stop the entrance of *any* air through a pipe which is soiled by soap and grease, and which is therefore offensive. The trap is placed as near the sink or bath as possible, and the most convenient form of trap is the S trap shown in the diagram. This will be seen to fulfil the requirements mentioned above; there should always be a screw plug at the bottom to allow of occasional cleaning of the pipe.

There are, however, two further possibilities of waste pipe traps going wrong—possibilities which are not likely to occur in gullies. (1) The discharge from above may be so strong as to wash right through the trap and leave no water behind ; this may be guarded against by making the trap narrow in section, and the pipe beyond larger and square, so that water does not leave the trap so rapidly as it enters it. (2) If the pipe beyond be long, and filled with discharge, the trap water may be sucked out by *siphon* action ; this can be prevented by *ventilating*

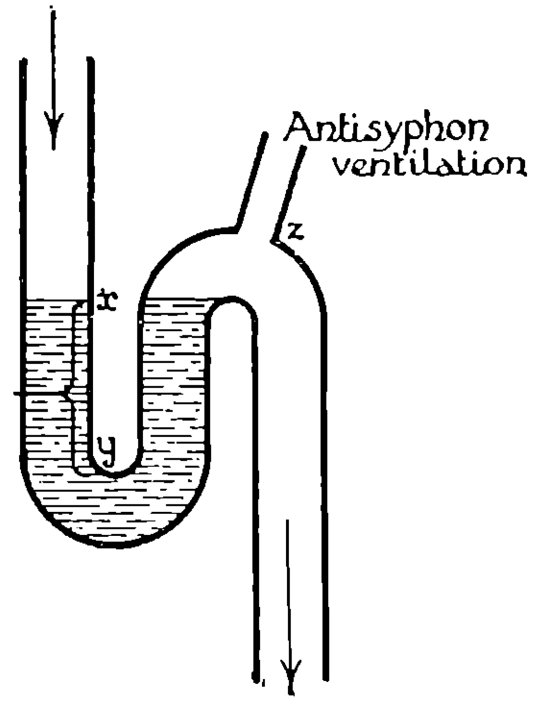

Fig. 42. S trap.

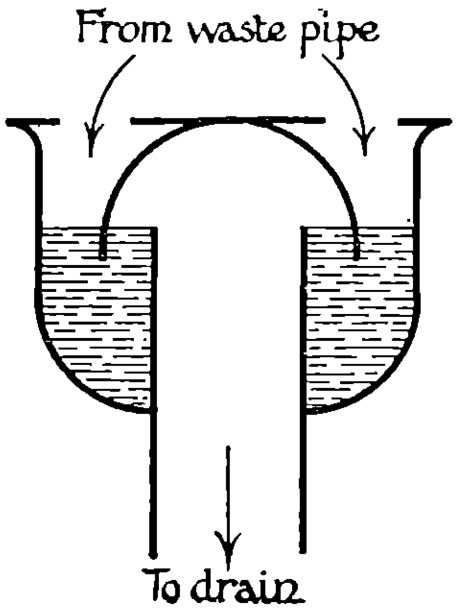

Fig. 43. Bell trap.

the pipe above and beyond the trap at the point marked z, so that the departing discharge may suck air in after it, instead of taking out the water in the trap.

Here it will be convenient to mention two forms of trap which are *not* efficient, but are still to be found. The *Bell* trap is often used in gullies ; the seal is very shallow, but, if made deeper, obstructs the passage of the water ; again, the trap is very apt to become choked with grease, and it cannot be cleaned without opening the drain.

The D trap, which was formerly very commonly used under water-closets, is another bad type, because, as is

readily seen, the water is *not* changed every time the trap is used ; not only this, but there is a great chance of solid matter actually remaining in the trap instead of being passed through.

Rain-water pipes should be treated like waste pipes—that is, they should be *disconnected* from the true drain, and discharge over *trapped* gullies. Here, we must mention the last danger in traps—a danger that is particularly liable to be present in rain-water systems, and will occur just the same whether a trap is good or bad. This is, that if a trap is unused for long the water may

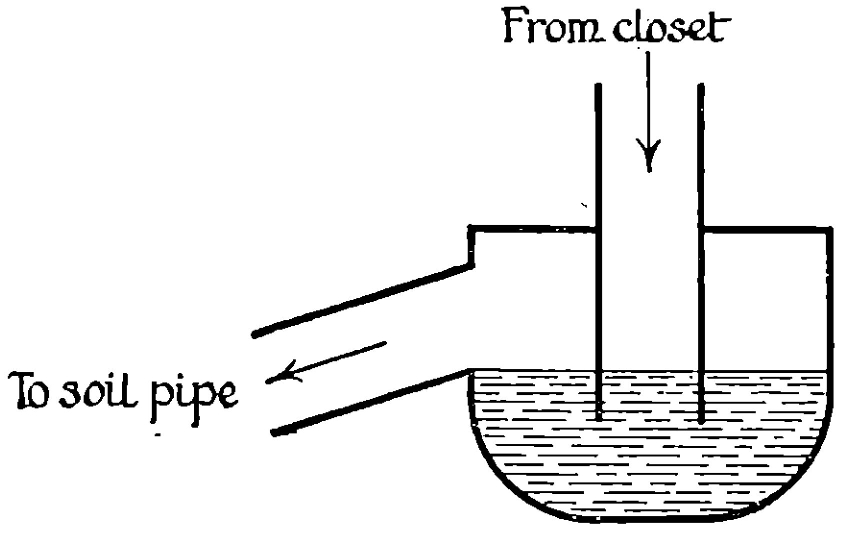

Fig. 44. D trap.

evaporate and the trap be left empty. Obviously, in dry weather, rain-water pipes will be carrying no rain water, and it is therefore a common practice to allow some of the sinks in the upper part of a house to discharge into the rain pipes, and so keep them sufficiently flushed. If this is not done the rain pipes must be separately flushed from time to time.

The five necessities of a trap may now be tabulated as follows :

(1) It must have a sufficient depth of seal.

(2) The water it contains must be washed away and replaced by fresh water each time it is used.

(3) It must not be emptied by the momentum of discharge from above.

(4) It must not be emptied by the suction of discharge beyond it.

(5) It must not be emptied by evaporation, as the result of disuse.

If the pressure of gas in a drain or sewer became really great it would force any trap : consequently *ventilation* is provided which allows gas to escape easily and also to escape harmlessly. Sewer ventilation will be described shortly ; drain ventilation is provided simply by continuing the end of the drain furthest from the sewer into a pipe, which is *of the same diameter as the drain*, and is carried through the ground and right up the side of the house, opening eventually into the air *above the roof* not only of the house itself, but of any houses closely adjacent. Gas issuing from this *ventilating shaft* will, therefore, not get through windows, but merely be dissipated in the open air. The top of the pipe is covered with a fine grating to prevent leaves falling in, birds building nests, &c.

At first sight it would seem that it might be convenient to use rain pipes as ventilating shafts, but there are two objections to this. (1) The rain pipe obviously cannot be taken above the roof of the house ; (2) the time during which most gas is forced out of the drains is when they are carrying away rain water, and consequently the rain pipe would be most needed for ventilation just when it was full of rain.

It is, however, a common practice to make the pipe which carries away discharges from water-closets and urinals—*the soil pipe*—act also as ventilating shaft.

Obviously, then, the traps under water-closets must be very perfect, *for there is no disconnexion*, and the trap is the only protection against the entrance of air. Where two or more closets at different levels discharge into the same soil pipes there is a special risk of the lower traps being emptied by siphon action, and this should be guarded against, as described on p. 226, by ventilation above the traps.

Apart from the trap the type of closet used is a matter of great importance, and the best closets are those in which there is least risk of the pan remaining dirty. It is unnecessary to describe the various types in use, and only one—which is known as the *wash-down*—is figured. The construction of this is very simple, and there are no rims or projections in the pan, nor is the pan long and narrow; as a result it is always kept clean provided the flushing arrangements are good. For these it is necessary that the cistern should hold two gallons of

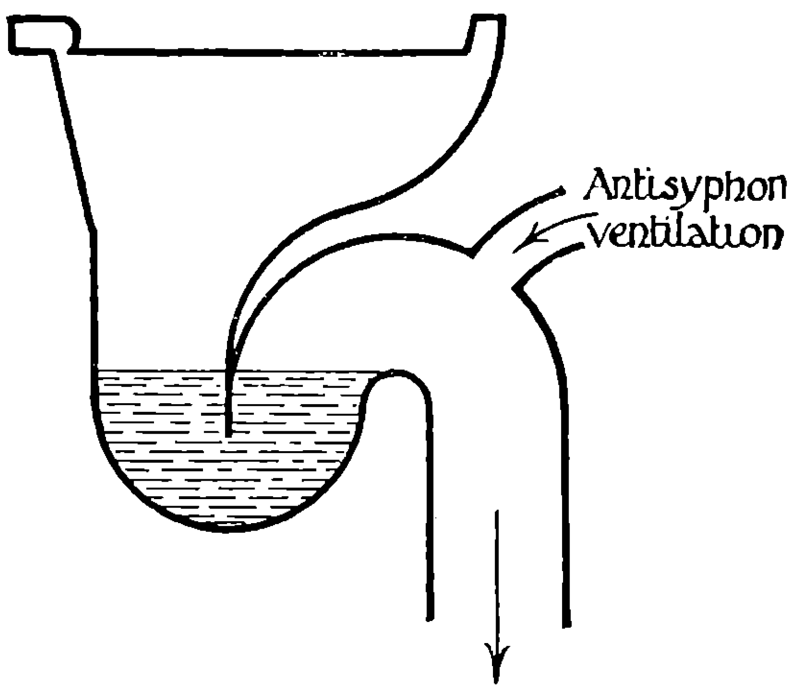

FIG. 45. Wash-down closet.

water, that the flow of water should be strong and sudden, and that it should be so spread out as to wash down every part of the pan. It is desirable for the whole closet—pan and trap—to be cast in one piece without joints. The evils of the D trap have already been mentioned.

The drain itself, as should now be clear, eventually receives all these classes of liquid waste; waste water from sinks, &c., and rain water, after disconnexion, and that from water-closets and urinals directly.

The drain runs towards the sewer, and, as a rule, sewer air is prevented from entering the drain by the insertion

of a trap near the junction of drain and sewer ; where this is done the drain should be ventilated on the house side of the trap ; this ventilation serves, mainly, the purpose of an *inlet* for air, and helps to purify the air in the drain, the ventilating shaft already described acting as an outlet.

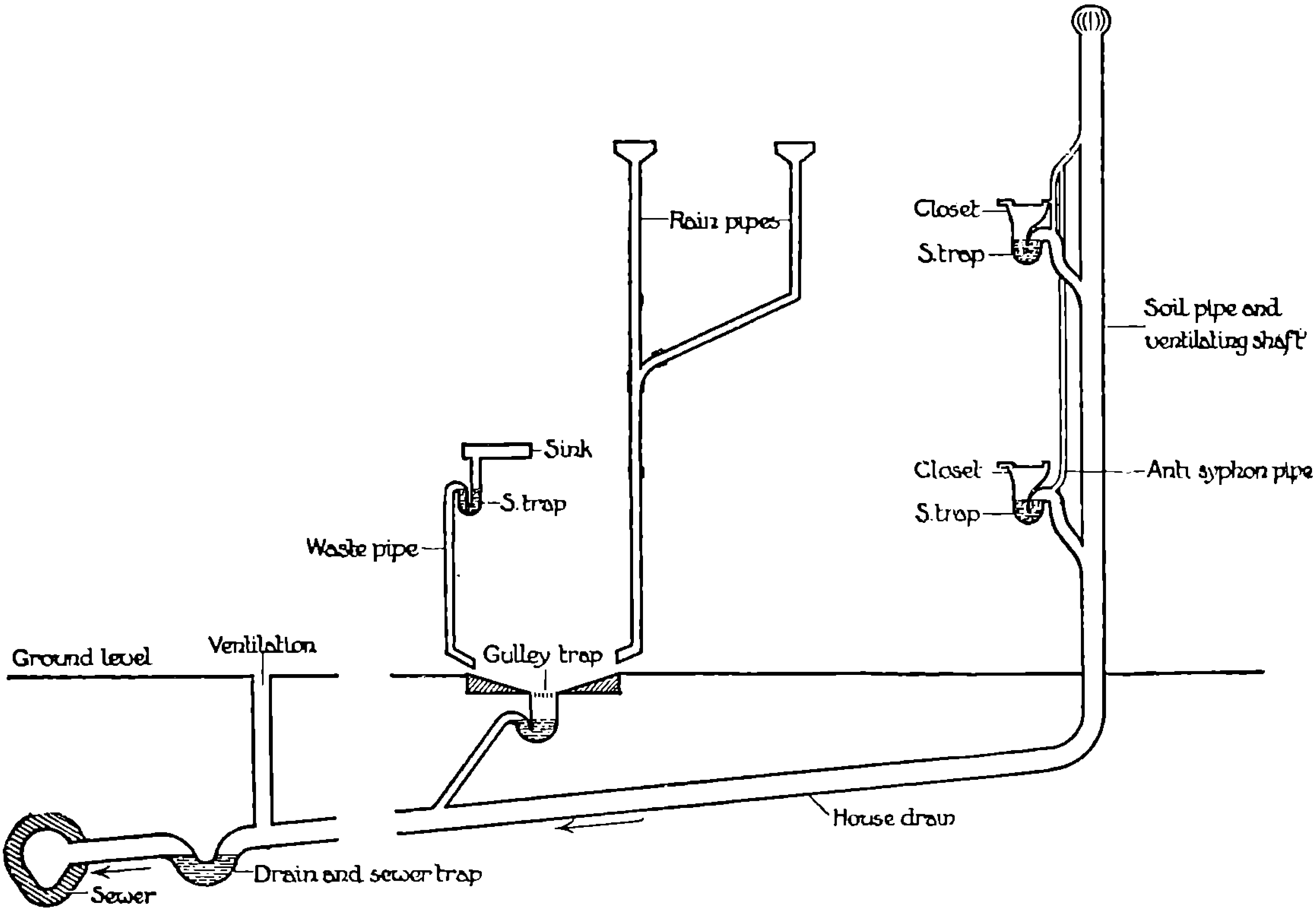

FIG. 46. Diagram of drainage arrangements. Note that there is neither trapping nor disconnexion between soil pipe and house drains. Note further that if all the other traps are efficient the trap between drain and sewer is not necessary.

Some authorities, however, do not consider this trap really necessary ; they hold, shortly, that as long as all precautions are taken to prevent *drain air entering buildings* it is not necessary, nor even advisable, to prevent *sewer air entering drains.*

The sewers themselves are like larger drains. In small

towns they may be made of large glazed earthenware pipes, but when larger they are egg-shaped tubes built of brick, covered with cement and laid in a bed of concrete. They are made egg-shape because they can then carry the water more quickly and easily when they are nearly empty. As with drains, all curves must be gradual, and all junctions oblique: the *fall*, owing to the greater size of the sewers, is less steep than in drains, but is slightly increased at curves and junctions.

At all important points 'manholes' must be provided, so that the sewers may be inspected and cleaned, and there should also be means of flushing through with plenty of water whenever necessary.

Besides the manholes, which are closed when not in use, there must be frequent openings, covered with gratings, to allow of ventilation; these openings act both as inlets and outlets and thus sewer gas escapes, but the openings are so frequent that the outside air is not appreciably affected; this is especially so when the sewers are properly cleaned and properly flushed, or, in other words, when the inside of the sewers is kept as pure as possible.

When the air of a properly kept sewer is analysed it is found to show no very great difference, as far as measurements go, from pure air; none the less, sewer gas has a definitely bad effect on health, which is due to the organic impurities present. Remember that sewers carry *trade effluents* as well as liquid refuse from dwelling-houses, and that some of these effluents are highly impure and offensive.

One set of sewers commonly serves to carry away both refuse and rain water, but sometimes the rain water is carried by a separate system. It is claimed that when this is done the ordinary sewers are more easily managed, and the sewage itself is more easily treated afterwards.

Disposal of Sewage. There are many methods of treating the sewage from *towns*. The simplest way is to let it run into rivers or into the sea. Running it into rivers is so bad a practice that nothing can really justify it:

when it is run into the sea the pipes should be carried far into the sea, and the sewage should only be allowed to escape when the tide is falling, so that it is carried out to sea and not brought in to land. This is a simple and cheap method of disposing of sewage, but can obviously only be used by towns near the coast. The chief objections to it are that the sewage is not always carried quickly out to sea, and that the flow from the pipes is not continuous but only during the ebb-tides.

The scientific methods of dealing with sewage aim either at *separating off* the organic matter, or at *destroying it*. In either case the water that remains is allowed to flow into rivers or the sea.

The best method of separating off the organic matter is to let the sewage pass through soil and so be filtered: the action of the soil in removing impurities is greatly increased by the presence of vegetation, and, commonly, the sewage is a very valuable manure for the vegetation. The filtered water will eventually drain off to a water-course.

If plenty of land is available this separation can be done by *irrigation* ; if not, by *filtration* through successive layers of soil.

The *bacterial methods* of treating sewage aim rather at destroying the organic matter than separating it: the sewage is first very coarsely filtered and then subjected in turn to two different kinds of bacterial action, with the final result that the organic matter is oxidized and rendered harmless.

Different methods are desirable at different places and under different conditions, and it is impossible to say definitely that any method is the best: one may say roughly, however, that the good bacterial methods are generally the most suitable, but that when plenty of land is available irrigation may well be employed, as the sewage is then put to a good use by increasing the richness of the land.

In *country* districts the arrangements are necessarily

less elaborate, and, as a rule, excreta are not removed with the liquid waste.

The *drainage* arrangements for the liquid waste should be just the same as in towns, but the drains themselves are usually conducted to **cesspools.** These can be managed in a perfectly sanitary manner, but great care must always be taken or they will be sources of danger. The cesspool itself must be *water-tight*, *covered in*, *ventilated*, and *not allowed to overflow*, but regularly emptied out at proper intervals, the contents being used for irrigation and manure.

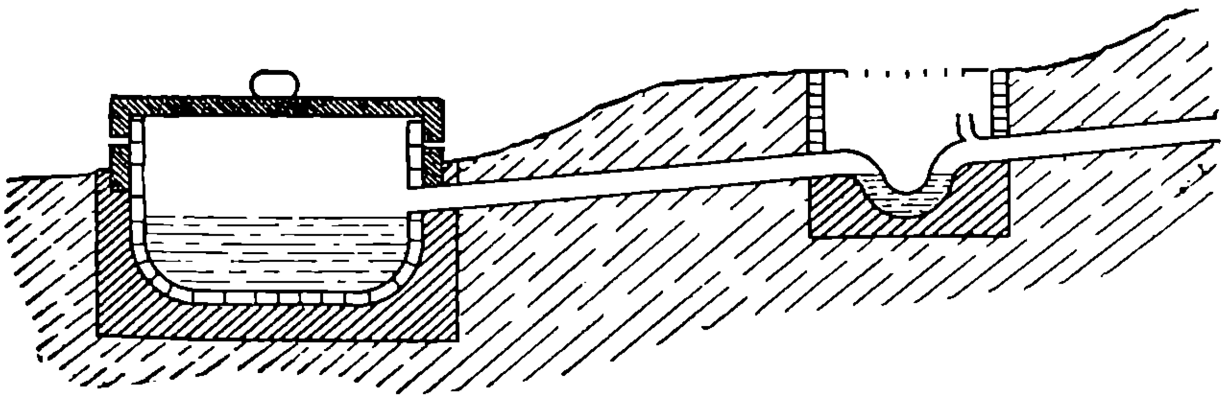

FIG. 47. Diagram of cesspool, showing also trapping and ventilation of drain.

Unless all these points are attended to a cesspool cannot be considered safe, and the chief risk is that of the contamination of wells in the neighbourhood. Even when a cesspool is perfectly constructed it must be placed at a considerable distance from any houses, wells, or roads.

The junction of drain and cesspool is treated on exactly the same principle as the junction of drains and sewers (see p. 229) ; that is to say, the drain and cesspool should be separated, as in the diagram, by an air-chamber and trap, the air-chamber ventilating the drain and also allowing for escape of any gas from the cesspool which may force the trap.

Dry refuse includes excreta, when these are not carried by water. Dry closets are necessary, and these must be placed *outside* the house. The necessary principles are

(1) to mix the excreta thoroughly with ashes (*ash closets*) or with earth (*earth closets*), and (2) to clear out the closets regularly. There are many contrivances for the former, and it is the duty of the owner of the house to see that they are always working properly, and that there is always a plentiful supply of ash or earth ; the latter duty must be the task of some regularly appointed person. The mixed contents of the dry closets, together with the other dry refuse, are suitably treated, after removal, and used as manure.

In towns where excreta are water-carried, dry refuse will consist partly of ashes, animal and vegetable refuse, paper, &c., from houses, and partly of road sweepings ; both classes of refuse need regular and systematic removal ; the latter can be used as manure, but the former are of little value for this purpose, and are generally destroyed by burning.

CHAPTER XIII

PREVENTION OF DISEASE

It was said, in the first chapter of this book, that hygiene, in aiming at the prevention of bacterial disease, has two main lines of action ; firstly, it wages direct war against all disease-producing bacteria, so that there shall be less chance of people being infected at all, and, secondly, it tries to build up resistance to these bacteria so that any people, who may actually be infected, shall have a better chance of overcoming the infection.

The first line of action has been apparent throughout the book in such examples as the purification of town water supplies, the regulation of the sale of milk and meat, the management of sewage and the like ; it is along such lines as these that hygiene can, at present, do its most effective work, for action lies chiefly in the hands of the public authorities acting on the suggestion of their scientific advisers, and success does not depend so greatly on the co-operation and knowledge of the people at large. Some more examples of this direct war upon bacteria—isolation, disinfection, &c.—will be discussed in this chapter, but for the present let us consider the second matter—that is, the building up of resistance.

Now we may safely say that the possession of a good constitution is of the very greatest help in the fight against *all* bacterial disease—that *a good constitution increases our immunity to all bacteria.* At the same time we must remember very carefully—because there is some tendency, when hygiene is studied, to forget it—that not all disease is bacterial, and that hygiene is not only concerned with bacterial disease. A nation may be entirely free of diphtheria and typhoid fever and tuberculosis and

all the host of infectious diseases and yet be unhealthy, simply because its people do not take proper care of their bodies and so cannot withstand the stress of ordinary life. It does, in actual fact, appear in modern civilized life that, though bacterial disease has been enormously diminished, other disease—*constitutional disease*—tends to increase; more people suffer from anaemia—that is, insufficiency of blood—from indigestion, headaches, short-sight, &c., from nervous breakdowns, and, last of all, from actual madness.

Now hygiene is concerned with these diseases, as well as with those caused by bacteria; it is clear, then, that the importance of the building up of a healthy constitution becomes doubly great.

We may say that a good constitution depends on *good air*, *good food*, *good work*, *good rest*, and *good habits*. At the present time very many people neither realize the value of these things, nor even know what they mean; in other words, hygiene has to contend with ignorance. In this, as was said in the first chapter, lies the importance of the dissemination of hygienic knowledge; no one supposes that disease will disappear like magic as soon as people know more about health and the value of health, for there will still be carelessness and indifference to contend with, and there will still be all the competition for a living, and all the poverty, that forces people to live in miserable houses and work long hours and do with insufficient food. Still, there is bound to be a gradual improvement in the *average* constitution of the people at large when the first laws of health are better understood. There is also the very important fact to be remembered that many people grow up with *no chance* of a good constitution, owing to their childhood being spent under bad conditions; this is not their fault, but they have to pay for it, and it is not, except occasionally, due to neglect on the part of their parents, but to *ignorance*, and if this ignorance can be corrected more children will grow up strong and vigorous.

Remember, then, that the foundation of all resistance to disease is the building up of a strong, healthy constitution; not only can we then better withstand all the strain and stress of ordinary life, but we are also more immune to all bacterial disease.

There are, however, various scientific methods by which our immunity to particular bacterial diseases can be increased, and two of these must be discussed.

Of the first method **vaccination** affords the chief example. Vaccination aims at producing immunity, not to any and every disease, but only to **small-pox.** Before we discuss the actual methods of vaccination, let us first consider the principles on which it is based and the facts which have led up to its use.

It has already been mentioned that attack by, and recovery from, a disease makes us more immune to further attacks *of the same disease*; this immunity is known as *acquired* immunity, and is obtained in most diseases but not in all; measles was given as a familiar instance of a disease in which this immunity results. This fact being known, the suggestion followed that it might be possible deliberately to give a person a *mild* attack of a disease, and thus render him free from the danger of catching the disease in a severe form, and this suggestion was put into practice to try and decrease the ravages of small-pox, the method used being known as **inoculation.**[1] A little of the fluid under the spots of a patient with a mild attack of small-pox was rubbed into a scratch in the skin of the person to be inoculated; with the result, in favourable cases, of a mild attack of small-pox followed by immunity. Unfortunately, however, the attack was not always mild, but sometimes fatal; unfortunately, too, other diseases besides small-pox were sometimes transmitted in addition.

Notwithstanding the grave dangers of inoculation, however, people were found willing to undergo the treatment rather than face small-pox unprepared. This

[1] Introduced into England from the East by Lady Mary Wortley Montagu in 1721.

is of importance because, now that small-pox is so rare, we are in danger of forgetting how terrible a disease it is ; when it does come it kills very many of those whom it attacks, and it disfigures most of those who do not die. The simple fact that people, in their fear of small-pox, were ready to face inoculation shows us clearly what small-pox meant to them.

Inoculation, with all its dangers, has now given place to **vaccination** ; it is, in fact, forbidden by law. The adoption of vaccination was due to a discovery, described by Edward Jenner in 1798, that *people who had been accidentally infected by cow-pox became immune to small-pox.* Cow-pox is a disease which affects cattle, and with which people who have to do with cattle may be infected ; it is not, even yet, quite certain whether cow-pox is really a very mild modification of small-pox, or whether it is merely an allied disease, but the fact discovered by Jenner remains true—that an attack of cow-pox makes one immune to small-pox, and vaccination means the deliberate infection of people with a mild dose of cow-pox.

The method employed is similar to that formerly employed in inoculation, but everything is done with much greater care ; a little of the fluid (which is known as lymph) lying under the spots of a healthy vaccinated calf (that is a calf with a very mild attack of cow-pox) is collected in a very fine glass tube, which is then sealed up. The skin—generally on the left arm or on the leg—of the person to be vaccinated is cleaned, and then scratched in three or four places just deep enough to let the blood appear, after which the lymph is rubbed well into the scratches.

In successful cases this procedure produces an extremely mild attack of cow-pox : spots appear on the site of the three vaccinated places, grow to their full size in about eight days, and later form scabs which drop off in about three weeks, leaving a scar behind them. The arm generally gives a good deal of pain for about three days,

and there may be a little fever at the same time; in some cases both the pain and fever may be more severe.

Vaccination may also be performed with the lymph from a healthy vaccinated child (arm to arm vaccination), but it is far safer and better to use the calf lymph; there is then no risk of what was formerly a distinct danger in vaccination—namely, the risk of giving the vaccinated person some other disease in addition to cow-pox.

Vaccination properly performed with calf lymph is almost absolutely safe, and is a very strong protection indeed against small-pox. This effect is not permanent, but gradually wears off, and in twelve years is comparatively small; if vaccination has been performed in infancy *re-vaccination* should be undergone at the age of twelve, and again if there is any epidemic of small-pox more than ten years after this.

The following are, very shortly, the proofs of the enormous value of vaccination:

(1) If there is an epidemic of small-pox a much smaller proportion of vaccinated than of unvaccinated people get the disease.

(2) Of those who do get the disease, vaccinated people get it in a much milder form.

(3) In all countries where vaccination has been introduced there has been, at once, a great reduction in the ravages of small-pox. Improved sanitary conditions might account for a *gradual* reduction in the death-rate, but cannot account for the sudden change that accompanies vaccination.

(4) This reduction has been most marked where vaccination has been *compulsory*; this is important, because it shows that unvaccinated people do not merely risk their own health but are dangerous to any community.

(5) Last, but not least, there is the very practical proof that vaccinated doctors, and vaccinated nurses, attend and nurse cases of small-pox without fear and almost without danger.

At present the law in Great Britain allows a person to be excused from vaccination, or from having his children vaccinated, if he can satisfy a magistrate that he has a 'conscientious objection' to the procedure; a large number of people avail themselves of this, and, consequently, there are many people who will be sources of danger to the community if another epidemic of small-pox comes to England.

Some of those who object to vaccination have really studied the matter, and have a real objection to vaccination; this is very difficult indeed to understand, but is none the less true. Some say that it is dangerous, and some that it is of no use notwithstanding the proofs that these statements are inaccurate. Others, again, say that it is dirty, and these are the most difficult of all to argue with, for if a man thinks a thing is dirty—well, he does think so and it is no good to point out that it is not.

Most, however, of those who object to vaccination are quite ignorant, and do so either because they do not want to be bothered, or because they do not want their children to have a sore arm for two days, or because some one has told them that it is dangerous.

Whether it would be right for every one to be *forced* to undergo vaccination is a question which cannot be discussed here; it involves the principle of 'the liberty of the subject', which is a very wide question indeed. The point to be remembered, as long as vaccination is *not* compulsory, is that unvaccinated persons are sources of danger; when small-pox comes it is they who will be attacked, and they who will spread the disease. Small-pox itself may be the stern teacher of the value of vaccination, in the future as well as in the past.

The acquired immunity which results from one attack of a disease, or, as in vaccination, from one attack of a disease in a modified condition, is known as *active acquired immunity.* A measure of immunity can also be induced in another manner, now to be described.

It was said in Chapter III that our powers of resistance

to disease lie in our blood ; partly in the white corpuscles, but primarily in the *blood plasma.* Suppose we develop measles ; after we have recovered we are much more immune to measles than we were before, and this means that some new substance has been manufactured in our blood plasma. The same thing happens when we are vaccinated ; a new substance, resistant to small-pox, is formed in our blood, and we manufacture this substance ourselves simply as a result of having the disease ; this is why this immunity is called *active* acquired immunity. Now suppose that some of the plasma of a person (or animal) who is immune to a disease is passed into the blood of a person who is not immune. Is it not possible that this second person may also become immune ?

This suggestion underlies the principle of the second method of rendering persons immune to particular diseases, but it is more convenient to use *serum* instead of plasma ; *serum*, it will be remembered, is practically *plasma minus fibrin* and the fibrin is not concerned with immunity, so that the serum contains the same resistant substances as does the plasma.

The 'serum' method of increasing resistance is most used in the prevention and treatment of *diphtheria*, and the serum is obtained from the blood of horses which have been rendered very highly immune to this disease by methods which do not concern us here ; it is sufficient to say that their immunity is very great indeed. The serum so obtained is injected under the skin of the persons to be treated, passes into their blood, and gives them a considerable degree of immunity to diphtheria. It is used very largely in the *treatment* of the disease, but also for the prevention of the disease in persons who have been exposed to infection, and the records of diphtheria epidemics show very clearly indeed that persons who have undergone the treatment withstand diphtheria far better than persons who have not. This method has also been used for other diseases, such as typhoid fever and lock-jaw, but the best results have been obtained with

diphtheria. Note once more the difference between the two methods: in the first *active* acquired immunity is produced by the patient manufacturing for himself a resistant substance, to overcome a mild or a modified attack of disease: in the second, *passive* acquired immunity is produced by the resistant substance being injected into the blood of a patient without his having to do anything himself. Passive immunity is, as a rule, neither so complete nor so permanent as active. It is clear that both methods represent special efforts to prevent bacterial disease, by increasing the resisting powers of the community.

Let us now return to the subject of the direct war upon the bacteria themselves. So far we have chiefly studied the means by which hygiene endeavours to prevent bacterial disease appearing at all; it still remains shortly to discuss the further work of hygiene—that is, the prevention of the spread of diseases from persons who have been attacked.

Now it is very clear that the first and most important thing of all is to prevent uninfected persons from coming into contact with the infections; in other words **isolation** of the patients must be the first matter attended to.

Isolation at home is a very difficult matter, and in serious illnesses, such as diphtheria, scarlet fever, or typhoid fever, it is nearly always best for the patient to be removed to a special hospital. With small-pox the 'nearly always' must be changed to 'always' no small-pox patient must ever be treated at home.

As a general rule, then, persons suffering from the more serious infectious diseases are removed to isolation hospitals or 'fever' hospitals, as they are more usually called. To make sure that the authorities shall have knowledge of infectious diseases being about, it is the duty of the doctor who sees the case to *notify* it: that is, to fill in a form giving the name and address of the infected person, and the disease from which he is suffering. The authorities then remove the patient, if desired, to the

fever hospital, where he is treated and kept until he is free from infection, so that, as far as possible, he is prevented from giving the disease to his friends and relatives or any others who might come in contact with him if he remained at home. At the same time the 'notification' is valuable for two other reasons: firstly for statistical purposes, and secondly because the authorities are able at once to make inquiries with a view to finding out *how* the person became infected, and to take steps to prevent the infection of other people from the same source; for instance, supposing it is a case of diphtheria and appears to be due to infection carried by milk, and the milk has all come from one particular dairy-farm, the condition of the dairy and the milk coming from it can at once be examined and, if desirable, the sale of the milk temporarily stopped.

The various diseases are, naturally, not mixed up with each other in the hospital, but are kept in separate blocks between which there is as little communication as possible. Small-pox cases are not merely kept in separate blocks, but in entirely separate hospitals, and these are placed a long way from any other buildings, and must be most rigorously isolated: the 'striking range' of small-pox is very great.

Let us now consider the precautions which must be taken to isolate cases of infectious disease which are treated at home; also the principles of **disinfection** which apply equally to hospital-treated and home-treated cases.

Both isolation and disinfection are harder to carry out at home; but they *can* be ensured in large houses at the cost of considerable trouble and expense.

The patient must first of all be taken to a room as detached as possible from the rest of the house; preferably high up, and on a separate landing or approached by a separate passage. When once he is there, everything possible must be done to prevent infection reaching the other inmates of the house. To prevent *direct* infection,

no one except those actually in attendance on the patient must be allowed to see him or even go near the room. Further, steps must be taken to prevent bacteria passing out of the door of the room into the house. It is customary to hang a sheet soaked in disinfectant outside the door, but it is much more important to have the room thoroughly well ventilated, so that there shall be a good 'outlet' to the open air instead of through the door; it is of great value to have a good fire burning continuously, and the windows open. When the patient is well, and past the infectious period, he should have a disinfectant bath, in which special attention is paid to the hair, and then put on clean clothes which have not been in the sick room; once out of the sick room the patient must not enter it again.

To prevent *indirect* infection several matters have to be borne in mind.

(*a*) *The risk of those in attendance carrying infection to other people.* The nursing, &c., must be carried out by the same person, or, if the illness is serious, by two persons, one doing day duty and the other night duty, and not by anybody who is about. Before entering the room the nurse should put on an overall which covers all her clothes: as soon as she leaves the room, the overall must be taken off, and the hands, arms, and face well washed with a disinfectant. If the hours of duty are long it is really better to change all the outer clothes altogether. The nurse also needs plenty of fresh air, and an outing every day. Even when all these precautions are taken intercourse with the other inmates of the house should be as limited as possible.

(*b*) *The risk of infection being carried by articles used in the sick room.* All plates, knives, dishes, trays, &c., which the patient uses must be kept for his use alone. Meals must be carried into the sick-room only by the nurse, and everything must be disinfected before it goes downstairs again. All clothes, and all bedclothes, must be disinfected before they are sent to the wash, and all other

articles must be similarly treated before the room is in ordinary use again.

(*c*) *The risk of infection remaining in the sick room after the patient has left it.* To avoid this the room, and all the furniture, carpets, &c., which it contains, are carefully disinfected, so as to destroy any bacteria which remain behind. Obviously, to make this process easier, it is wise to have as little furniture as possible in a sick-room.

Special precautions have also to be taken with the patient's excreta, and these should at once be disinfected with some strong solution, and afterwards removed; the best thing to do is to burn them. This precaution is specially necessary in cases of typhoid fever, as it is through the excreta that the disease is generally spread; in this disease, in fact, other precautions need not be so stringent, and it is common to see typhoid fever cases in the wards of general hospitals.

The discharges from the mouth and nose—from coughing, blowing the nose, &c.—have also to be rendered harmless. Either clean linen rags or paper handkerchiefs can be used in place of handkerchiefs, and immediately burnt, or spittoons can be provided containing a disinfectant solution.

Disinfection, or 'cleansing from infection' practically means 'destruction of bacteria'; nothing can be said to be truly disinfected until all bacteria on it or in it have been killed. There are, broadly speaking, three methods of producing disinfection: (1) by the use of heat, (2) by the use of germ-destroying liquids, and (3) by the use of germ-destroying gases.

(1) **Heat** is by far the most perfect disinfectant, and should always be used when possible. It has its limitations because it obviously cannot be used to disinfect persons, nor can it be used for valuable articles which it might destroy as well as disinfect; nor can it be used to disinfect a room or a building.

Its uses are, however, very wide, and one can be *certain* that if the temperature of an article has been properly

raised, that article will be free from infection. The simplest way to use heat is to put the infected articles into water and then boil the water for ten minutes: this is the method used in disinfecting surgical instruments, and the like. It also disinfects the water itself, and, as mentioned in Chapter VI, a similar method is used for the 'sterilization' of milk. It should be clear that 'sterilization' and 'disinfection' really mean very much the same thing; disinfection simply signifies an attempt to sterilize an article which has been known to be exposed to infection, and disinfection has not been perfectly performed unless sterilization has been attained.

Obviously we cannot put all things into water, and boil them up; some are too big and others would be ruined. Heat can, however, be applied by the use of *steam under pressure* or *hot air*. Of these, steam under pressure is by far the best, partly because not so great a heat is needed, but more particularly because steam *penetrates* much better than hot air. Suppose a bolster or a mattress has to be disinfected; it is almost impossible to raise the temperature of the inside of these to the proper height by the use of hot air, but it can be done certainly with steam under pressure, and it is the proper practice to hand over all portable articles of any value to the public authorities at the end of an infectious illness and have them disinfected by these means. Clothes, bedclothes, mattresses, towels, sponges, &c., are practically uninjured; books are certainly not improved, but are not destroyed. It is wise to let patients, who treasure their books, only read paper books which can afterwards be burnt; all cheap and valueless articles may be similarly treated. Heat cannot be used to disinfect articles made up with glue.

Remember, then, that heat is the most perfect disinfectant and should be used whenever possible.

(2) **Germ-destroying solutions** are in constant use in the course of an illness, and must be used for the final disinfection when heat is not admissible. It must be

remembered that all solutions take time to act, and do not destroy germs instantaneously, and it is, obviously, of the greatest importance to know what strength of solution is needed to produce a strong effect. The solutions chiefly in use are

Carbolic acid. Strong solution = 5 %, or 1 in 20.
Perchloride of mercury. Strong solution = ·001 %, or 1 in 1,000.
Potassium permanganate. Strong solution = 5 %, or 1 in 20.

There are also various other disinfectants of value sold already in solution, such as Lysol, Izal, and Jeyes' fluid.

It will be seen that perchloride of mercury (a salt of mercury and hydrochloric acid, and also known as corrosive sublimate) is extremely powerful, and is used in very weak solutions. It must be used with care, for it is also *very poisonous*, and, further, has a harmful effect on steel or other metal articles; used with care it is perhaps the best liquid disinfectant of all. Carbolic acid has the advantage of not injuring instruments.

Twelve hours' immersion in these liquids, of the strengths given, is necessary for *certain* disinfection. They should, however, be in constant use in weaker solutions for washing down floors, window-sills, furniture, mantelpieces, &c., and for keeping the damp cloths used for cleaning plates, dishes, and the like. The full strength should be used for the reception of expectoration and excreta.

Liquids *can* be used for the final disinfection of rooms, the wall-paper being stripped off, and the walls, floors, and furniture thoroughly washed over with a strong solution; but it is better to use

(3) **Germ-destroying gases.** All the crevices of windows and ventilators are closed, as far as possible, by pasting brown paper over them, and the chimney opening is closed up. The furniture is disposed over the room, drawers being opened; and anything else left in the room is freely exposed. The apparatus to be used for setting

free the gas is then set in action, and the room is left empty, the outside of the door being at once pasted with brown paper: the gas is then allowed to produce its effect for from twelve to twenty-four hours, after which doors and windows are opened wide and the room fully ventilated. By this means everything is exposed as freely as possible to the germ-destroying fumes, and leakage of the gas is reduced to a minimum; if the crevices are left open the fumes escape so rapidly that their strength is greatly reduced. This treatment of a room is known as *fumigation.* The gases most commonly used are

(1) *Sulphurous acid gas.* This is obtained by simply burning sulphur: to avoid risk of fire the sulphur is burnt in a small iron vessel suspended over a bucket of water.

(2) *Chlorine.* This is produced by adding hydrochloric acid to chloride of lime. The gas is generated with great rapidity and is very poisonous. It is, therefore, wise to have an apparatus which only allows a gradual drip of the acid, so that the operator may escape from the room before much gas is produced. Both sulphurous acid and chlorine are more effective if the air of the room has been moistened by boiling a kettle of water in it beforehand.

(3) *Formalin vapour.* The formalin is vaporized in some specially devised lamp, and is therefore not so simply obtained as the other two fumigators, but it is, perhaps, the most effective of the three: it acts best when the air is dry.

Formalin is also largely used in the disinfection of rooms in the form of a spray, with which walls, floor, ceiling, and everything else in the room are treated in turn; it is claimed that this treatment is not only quicker and simpler, but also more effective than fumigation.

Details of the symptoms and nature of the various infectious diseases are quite out of place in this book, but there is one disease which is so widespread and so fatal, and, equally important, so *preventible,* that it needs

some special discussion; this disease is known as **tuberculosis,** or, in by far its commonest form, as **consumption.**

The prevention of tuberculosis is not a matter that lies entirely in the hands of the authorities; it depends, to a special extent, on the knowledge and co-operation of the public itself, of those who are infected with the disease, of those who nurse the patients, and of those who are unaffected. The stamping out of the disease will, in any case, be a work of time, but there can be no doubt that if people do their best the danger will decrease enormously; for many years there has been a gradual reduction of the numbers of persons attacked, but this reduction has not been nearly great enough. And there are still from forty to fifty thousand deaths in a year from tuberculosis in England and Wales.

The germ that causes the disease is well known; it is a rod-shaped baccilus, the length, which is about $\frac{1}{8000}$ inch, being roughly ten times the breadth.

Infection is generally produced by *inhalation*; that is, the germ enters our bodies with the air we breathe. Though this is by far the chief source of infection, there is another route by which the germ may enter our bodies, namely by being *swallowed* with our food, and, particularly, with milk.

If the resistance of the body is overcome the bacilli settle down in various parts of the body, where they produce disease, which sometimes very quickly, but generally quite gradually, spreads from its original focus, wastes away the tissues in which it is placed, forming abscesses and cavities, and eventually causes death.

Now by far the most common and most fatal site of tuberculosis is in the *lungs*; it will be clear that it is comparatively easy for the germs to reach the lungs when one bears in mind that the common route of infection is with the air we breathe. Besides the lungs, tuberculosis is apt to settle, especially in children, in the *abdomen*, the *joints*,

the *glands of the neck*, and in the *membranes of the brain*, this last being a very fatal but, fortunately, not very common site.

The lungs are, however, most commonly affected, and most of the deaths due to tuberculosis are due to tuberculosis of the lungs: the extent of disease in these organs may be very great indeed, and a great deal of tissue may be wasted away; hence the name 'consumption'. During the process there is a tendency for the blood-vessels, no longer supported by healthy tissue, to give way, and this gives rise to the coughing up of blood which is so well-known and so dreaded a feature of the disease.

Now the bacilli of tuberculosis are so widespread that it is highly probable that every one becomes infected at some time or another, and that many people are frequently infected yet we do not all get the disease. Not only this, but it has been found when the bodies of people who have died from other diseases have been examined, that a very large proportion of these show that the disease has at some time or another laid definite hold on the body but has afterwards been overcome, though it has left its mark behind it: in many, if not most, of these cases the person affected has no knowledge that he has ever had tuberculosis.

What do these facts mean? They can only mean that the body has a great power of resistance to the germs of tuberculosis, and that even when these latter gain entrance to the body it is not a foregone conclusion that they are going to do harm. On the contrary, it appears that the chances of success really lie with the body; not only is it certain that the germs very often indeed make no impression at all, but also that they may make great headway and yet be killed off eventually. And yet forty to fifty thousand people die in England and Wales of this disease in a year.

Now, when we bear all these facts in mind, and also remember that the results of a bacterial infection depend partly on the numbers of infecting bacteria, and partly on

the resisting powers of the persons infected, it becomes quite clear that this great number of deaths will be enormously reduced if we can make infection less extensive and less frequent, and at the same time make the average resisting power of the nation more effective.

It is altogether wrong that a germ *against which we naturally have the best of the fight* should have such tremendous powers for evil.

The question of increasing resistance is, as usual, largely a matter of the education of the people; in no other disease are the advantages of good food, good air and good habits of so much importance. In particular, the necessity of sunshine and fresh air is very great, and this has been proved over and over again by the decrease in tuberculosis which has resulted when the life in such places as workhouses and prisons has been made more hygienic; when, that is, the inhabitants have had the chance of more fresh air and sunlight, and better food.

The war against the tuberculosis bacilli must be waged on somewhat different lines to that against most infectious germs, because it is not right to *isolate* persons suffering with this disease, for they may be but little ill and quite able to do work and earn money.

The three great things to remember are (i) in the early stages it may be very difficult to detect the disease, (ii) if the disease is recognized early it is very probably curable, and (iii) any person with the disease may spread it to other people, and this is especially likely if he does not know he has got it.

It is of the utmost importance, then, both to the individual and to the community, that any case of the disease *should be recognized as soon as possible.* There is then a much better chance of the individual being cured, and a much smaller chance of other people being infected. It is of great value, then, to know something of the *early* symptoms of the complaint, so that either the person attacked or his friends may know what should rouse their suspicions.

The most important early symptoms are
(i) *Loss of weight for no apparent reason.*
(ii) *A persistent cough, however slight it may be.*
(iii) *Loss of energy.*
(iv) *Anæmia.*
Besides these there is (v) *blood-spitting*, which has been purposely left to the end, not because it is unimportant, but because many people believe that it is the first sign of all, and that if they have not got this they have not got consumption. This is a very serious mistake, because blood-spitting is often *not* one of the earliest symptoms ; should it come it is a very important symptom, but it should never be waited for.

If any of these symptoms appear (for more than a few days) the person suffering should go (or be sent) to a doctor, and be thoroughly examined. If tuberculosis is found he has a good chance of being cured, if he is careful and carries out his doctor's instructions.

Now, to be cured is obviously the best thing for the patient ; we must remember that it is also the best thing for hygiene, because the best way of all to stop a man spreading a disease is to cure him.

While he is being cured, or if he cannot be cured, he and those who look after him should see that he spreads the disease as little as possible. The following points are important as tending to prevention of spread :

(1) The patient should sleep in a separate room.

(2) He should live, day and night, with constantly open windows.

(3) The rooms he occupies should be free of unnecessary curtains, hangings, mats, rugs, &c., in which myriads of germs may lodge.

(4) He must always spit into a spitting-cup containing disinfectant solution, or into a rag or proper handkerchief which is afterwards burnt.

(5) He should have separate eating utensils, and these should always be washed and kept apart from the others in the house.

(6) He must remember that when he kisses other people he exposes them to danger.

A word more must be said about the dangers of spitting. The expectoration of consumptives contains myriads of tuberculosis germs, and when the expectoration dries, these germs, which remain alive for a long time, are easily carried about in the air, and so may be breathed by other people. The danger caused by consumptives spitting in the streets or in railway-carriages, tram-cars, and the like is very clear, and we have to remember that *very many people who are consumptive have no knowledge of the fact.* It is of little use only to forbid spitting in public by persons who know they have consumption, but the habit, which is, at the best, a very filthy habit, should be forbidden to every one ; if this could be done, one of the greatest causes of the spread of consumption would be abolished.

There can be no question that if cases of tuberculosis can, on the average, be more early recognized, and if those who suffer from it can be brought to understand what they should do to cure themselves, and to save infecting other people, the power for evil of this disease will steadily diminish, and should, eventually, nearly disappear.

When consumption is abolished there will, however, still be plenty of scope for the activities of Hygiene.

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